WHERE DISCOVERY AND INNOVATION MEET

FALL 2017
VOLUME 3, NUMBER 2

insights

THE RESEARCH CHRONICLE OF THE **COLLEGE OF SCIENCE AND MATHEMATICS**

Jellyfish Invasion

Researchers study the toxins, tentacles and DNA of New Jersey's newest annoyance

Montclair State University

FROM THE DEAN

The Creative Scientist

Stereotypes of scientists abound – but rarely does the description of "a creative type" conjure up the image of a scientist. A creative person has originality of thought and expression, and is open to transcending traditional ideas, rules and patterns to create meaningful new ideas or interpretations. Of course, scientists are creative! We work to put the pieces together, to ask the right questions and perform experiments that lead to more questions. Astronomer Carl Sagan once noted that, "It is the tension between creativity and skepticism that has produced the stunning and unexpected findings of science." It is indeed these unexpected findings that nudge science forward, sometimes in small increments and sometimes in major "eureka" leaps. In fact, modern science has become so large and so complex that many of the biggest challenges require scientific teams that extend their creativity by combining fields of expertise and approaches in new ways.

College of Science and Mathematics (CSAM) scholars embrace the call to be creative and keep their minds open to the unexpected, unusual or unpredicted result. In this issue of *Insights*, scientists, mathematicians and educators explore important questions and answers, adding to the body of scientific knowledge that continues to evolve and change over time. Questions like: How did those tiny-but-painful jellyfish native to the Pacific Ocean wind up in New Jersey and just what are they packing in those little stinging cells? How does the complex microbiological community of microscopic organisms found in soil actually perform a controlling role within the entire ecosystem? How can hyperspectral imaging and super-computers keep us safer? How do we know gravitational waves exist and why should we care if we can't physically feel them here on Earth? And how can we harness creativity in STEM to produce better scientists and citizens?

CSAM is drawing upon its depth of creativity to address these challenges and many others. For the last 16 years, CSAM was led by Robert Prezant, a creative scientific thinker in his own right, who grew the college into one fitting of a designated national research doctoral university. Now the Provost at Southern Connecticut State University, Prezant leaves behind a thriving scientific community. I am proud of all our CSAM scholars and excited that together, we will build on our strong foundation of research, community involvement and academic achievement.

Lora Billings
Acting Dean
College of Science and Mathematics

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The Research Chronicle of The College of Science and Mathematics

Insights is collaboratively produced by the College of Science and Mathematics' research faculty and members of the dean's staff in an effort to broaden awareness and understanding of the scope and relevance of the College's research initiatives as well as the critical role research plays in preparing the next generation of scientists.

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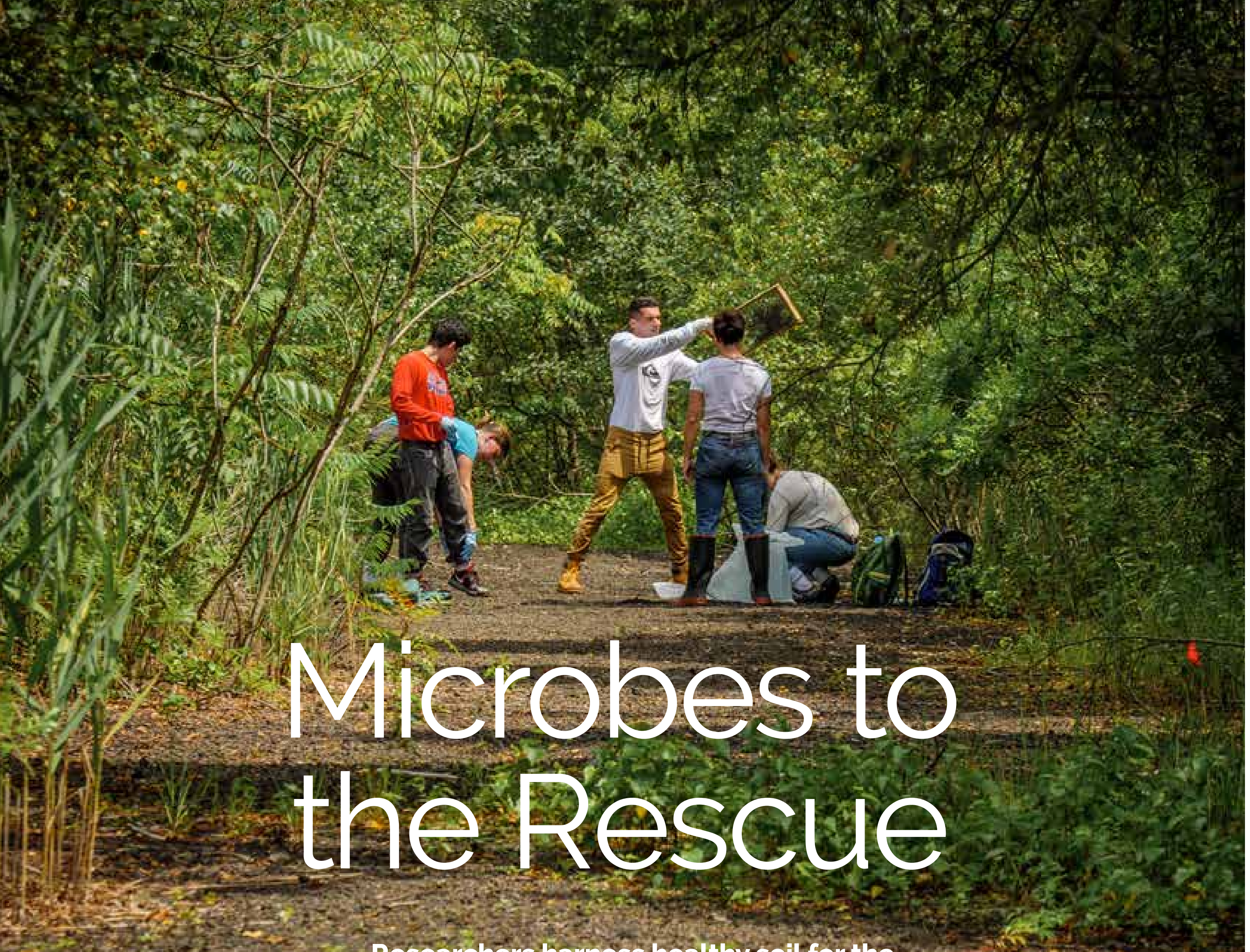


Microbes to the Rescue

Researchers harness healthy soil for the "greening" of brownfields

Contaminated soils that are a legacy of industrial use are often a characteristic of urban environments. The New York metropolitan area is such a case, but contaminated sites within it can surprisingly support a seemingly healthy ecosystem.

Liberty State Park in Jersey City, New Jersey, is a brownfield that was once a railyard built on landfill of debris and soils from development in New York City. A portion of what is now the park along the Hudson River was remediated by removing the contaminated soil and replacing it with clean soil. A large portion of the park lies behind a fence and is still heavily contaminated with heavy metals and unknown organic pollution. Nonetheless, in most areas the soils behind the fence have supported a diverse successional forest. In some areas, however, the contaminated soil functions poorly as demonstrated by limited enzymatic activities and low plant cover.

Biology and biochemistry professors and students have been working at the brownfield site at Liberty State Park, transferring microbes to the soil to aid in ecosystem restoration.

Restoring soil function in degraded, often urban or post-industrial sites, will also restore ecosystem health and plant growth, bringing back green areas to the state, and enabling the use of phytoremediation techniques to remove contaminants from these soils. Building on their earlier findings, biology Professor Jennifer Krumins and Biochemistry Professor Nina Goodey, along with students and other faculty, are collaborating to develop new practices of soil microbial community "transplants" that may increase soil functioning and ultimately aid in ecosystem restoration.

With a three-year grant of $330,000 from the National Science Foundation, the group has shown that microbial communities in the park's soil can be surprisingly healthy and functional despite the presence of contaminants.
"The microbes in the highly functional soils will be transplanted or seeded into lower-functioning sites with the aim of increasing soil health," says Goodey. "High-functioning and healthy soils will be the foundation upon which phytoremediation can succeed and healthy ecosystems can build."

Goodey and Krumins, together with Earth and Environmental Studies Professor Mike Kruge and students Diane Hagmann and Mathew Chung, are characterizing organic contamination in the fenced area of Liberty State Park. In the Krumins lab, students Jay Singh, Fathima Idris and Jennifer Balacco are cultivating test plants and characterizing microbes on the roots of plants. Microbial characterization is also being examined through a collaboration with Valdis Krumins of Rutgers University. In addition, Jennifer Krumins' students collaborate heavily with Bhagashree Vaiyda, a student of Goodey's who is carrying out enzyme assays. In the future, the project will develop mathematical models to describe the ecological system in the area by collaborating with Montclair State Mathematics Professor Eric Forgoston.

"The implications of this work are far reaching," says Montclair State's Krumins. "Not only will the work inform restoration practices, but also it will increase our understanding of the health and functionality of urban ecosystems."

Since urban land cover is growing rapidly globally, the often unique ecosystems and communities of urban areas will be important to the health of human habitats. Thus, says Goodey, "this project that informs basic ecology within the context of urban environments also answers questions about the microbiome of these habitats and their stability in the face of climactic and other environmental change."

Professors Jennifer Krumins and Nina Goodey contributed to this article.

Connecting the Dots

...from the economy to the environment

For Pankaj Lal, an Earth and Environmental Studies professor and the associate director of the PSEG Institute for Sustainability Studies, moving toward a renewable energy economy is the key to achieving the universal goal of a sustainable and prosperous future for humans and the planet.

As an environmental economist, Lal works to understand the economic value of various aspects of environmental science problems. While conducting environmental economics research in areas spanning bioenergy, conservation, resilience, ecosystem management and policy, Lal and his students are also tackling interdisciplinary research questions that straddle environmental, energy and economic systems.

"Bioenergy has supported our energy needs for several centuries, beginning with rudimentary forms such as fuel wood to today's more sophisticated fuels such as cellulosic ethanol," explains Lal. "Cellulosic bioenergy, in particular, presents a significant potential – especially against the backdrop of volatile oil prices, a need for energy independence and support for agricultural systems."

Pankaj Lal and researchers

Yet much remains to be learned about the economic, environmental and social consequences of large-scale biofuel development. Lal is currently directing three separate studies funded by the National Science Foundation, U.S. Department of Agriculture and U.S. Department of Energy, respectively. His research analyzes energy efficiency and emissions of biofuels vis-à-vis nonrenewables and assesses the impacts of grass- or wood-based biofuel industry development.

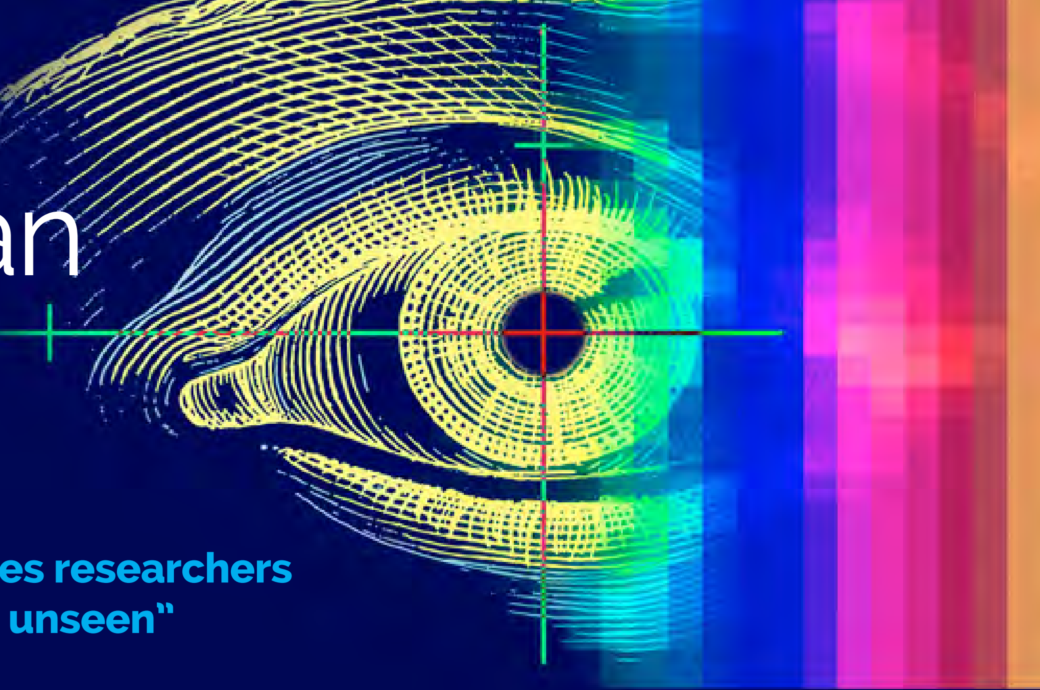
Lal also investigates the potential consequences on a wide range of issues, including impacts on poor- and minority-dominated counties in the Southern United States; economic consequences for forestland owners and farmers in the nation's Southern and Midwestern states; and the broader implications on environmental systems. "My research contributes to a better understanding of these complex issues and the ways through which agricultural and forest-based biofuel and the bio-product industry can develop in a sustainable manner," Lal says. His work presents an excellent opportunity for complementary, cutting-edge research between academic universities, government think tanks, and private and nonprofit organizations.

His research portfolio includes nearly $10 million in grants and contracts for research as a principal investigator or co-principal investigator not only from the U.S. Department of Agriculture, but also from the U.S. Department of Energy, New Jersey Department of Environmental Protection, the U.S. Environmental Protection Agency and the NSF.

President Obama awarded Lal the prestigious Presidential Early Career Award for Scientists and Engineers in 2017, and in 2016 Lal received a $450,000 National Science Foundation Faculty Early Career Development grant. A dedicated teacher, he guides and mentors several graduate and undergraduate students to help them develop into high-quality researchers.

"Receiving presidential validation of the research we're doing gives me added confidence to continue on with my sustainable energy and resources research, which is one of the grand challenges facing modern society," says Lal.

Professor Pankaj Lal contributed to this article.



More Than Meets the Eye

Supercomputing gives researchers a chance to "see the unseen"

A simple child's decoder toy of past decades was a picture that, when covered by a sheet of transparent red plastic, revealed a hidden message – like magic. Today, through hyperspectral imaging, otherwise hidden information can be revealed in images that are important in a variety of fields, including defense, agriculture, geosciences, medicine, nanotechnology and microscopy, archaeology, conservation, food science and quality control, with practical applications ranging from face recognition to monitoring the health of crops.

"Hyperspectral imaging technology was developed only a few decades ago and continues to grow in impact and importance," says Computer Science Professor Stefan Robila.

Hyperspectral images (HSI) are formed as collections of hundreds of images, each corresponding to a narrow interval of energy wavelengths. The data collected are not simply a detailed representation of the color intensity in the scene observed but often expands to other areas of the spectrum such as ultraviolet and infrared. Collected by using specialized cameras, such images allow researchers and practitioners to extract minute details not noticeable with the naked eye or through traditional video or photo recordings. In a sense, the use of hyperspectral imaging allows us to "see the unseen."

Since joining Montclair State University in 2003, Robila, with the help of his students, has developed and tested a variety of new algorithms for hyperspectral data processing. Their studies have led them to collect a number of image databases and identify new applications of this technology. Robila's Computational Sensing Laboratory maintains a hyperspectral camera and a variety of light sources unique to the campus and the region. Through the years, students from Montclair State and other colleges as well as local area high schools have collected images of faces (thus spearheading new research in face recognition), fruits and vegetables (as a study for ripeness and blemishes) and common vegetation (in studies of camouflage detection).

Today, HSI data sets are growing in both size and diversity. Satellites equipped with HSI cameras regularly add time-dependent series of images to large databases maintained by both private and government agencies – for such things as mining and agriculture in the private sector and defense and intelligence for government.

Moreover, HSI data are also frequently combined with other observations such as Light Detection and Ranging (Lidar) or higher resolution imagery collected with visible or infrared cameras. Simple computing techniques are no longer suitable to support processing of such big data collections. Meeting these challenges, Robila's research is currently examining the use of high-performance computing for processing hyperspectral data.

Supported by funding from the National Science Foundation, Robila is currently developing a framework for spectral data processing on a distributed environment. This innovative framework will start by designing specifications for data input formats as well as integrate with current renewable spectral data sets. Next, a subset of representative processing algorithms will be designed and implemented followed by the development of a web-based interface that will allow researchers to access the framework. The framework will be developed using the computer clusters acquired with the NSF support and housed in Montclair State's data center.

"By working with data produced by HSI sensors and using high-performance computing equipment able to perform large amounts of computations in a short time," says Robila, "we hope to enhance our ability to sense and understand the world around us."

Professor Stefan Robila contributed to this article.

Jellyfish Invasion

Researchers study the toxins, tentacles and DNA of New Jersey's newest annoyance

Biology Professor Paul Bologna and his students deliver tiny clinging jellyfish to Jenkinson's Aquarium in Point Pleasant.

Ephemeral, mostly water, drifting mindlessly through our seas, jellyfish are ancient and treacherous creatures that in recent years have become a problem in New Jersey's bays and rivers and along its shores.

Frequent visitors to Barnegat Bay are familiar with the ubiquitous sea nettle, New Jersey's unofficial jellyfish. Its annoying (and somewhat painful) stings have put a damper on recreational fun and frustrated fishermen for decades. There have been occasional Portuguese man-of-war sightings. And a tiny, clinging jellyfish, discovered last year to be in New Jersey by Montclair State biology professors Jack Gaynor and Paul Bologna, also seems to now be calling the state home.

"This year's individuals appeared to bloom at the same time as last year's," says Bologna, who is also director of the Marine Biology and Coastal Sciences program at Montclair State. "This suggests that annual blooms may become a common feature in New Jersey."

Gaynor says the polyps appear to be hearty individuals. "It's the polyp phase of the life cycle that persists from season to season and may be the reason for the return of the jellyfish to the Shrewsbury River," Gaynor says.

Experts on numerous jellyfish, Gaynor and Bologna have been studying jellyfish in New Jersey for years.

Gaynor focuses on DNA studies as well as investigations of jellyfish toxins aimed at possible new biopharmaceutical agents. Bologna looks at the ecology of jellyfish habitats and the impact jellyfish have on other species that inhabit New Jersey's waters.

In June of 2016, Gaynor, Bologna and their research students first noticed a new and unexpected visitor to New Jersey waters: the clinging jellyfish. Scientifically known as Gonionemus vertens, this diminutive hydrozoan can really pack a punch.

According to the New Jersey Department of Environmental Protection, victims of clinging jellyfish can suffer excruciating pain, muscle weakness and serious medical problems, including kidney failure. The sting from this species can be so severe the one New Jersey resident stung in 2016 was hospitalized for three days and needed morphine to control the pain – even though his exposure to the tiny creature was brief.

So called because of its proclivity for clinging to blades of sea grass, this quarter-sized jellyfish was first spotted in the Manasquan River, in Point Pleasant, near the inlet to the canal that connects to Barnegat Bay. Shortly thereafter, hundreds of clinging jellyfish appeared in the Shrewsbury River in Monmouth County.

"I've been working in eelgrass beds in New Jersey for over a decade and have never seen these jellyfish until last year," says Bologna.

Native to the Pacific Ocean, the clinging jellyfish first appeared in the Cape Cod area in 1894, all but vanished in the 1930s when the eel grass died out, and then reappeared in the 1990s. At that time, scientists in Woods Hole, Massachusetts, said the clinging jellyfish seemed to be moving south.

So, how did this mysterious creature get here? That's still a mystery, but DNA barcoding analysis in Gaynor's laboratory suggests this visitor came from the South China Sea, probably hitchhiking a ride in the ballast water of a container ship.

With continued funding from the New Jersey Department of Environmental Protection, Bologna, Gaynor and their research students monitored the coastal waters of New Jersey throughout the summer, keeping a watchful eye for both larval and adult forms of this unwelcome newcomer as they also conducted studies of both the clinging jellyfish and its more familiar, but also annoying, jellyfish cousins.

The team has set up a clinging jellyfish habitat in their lab. "We've installed a large tank with both males and females that will breed, and produce polyps," explains Gaynor. "This is a self-propagating colony that we could keep going for years."

Professors Paul Bologna and Jack Gaynor contributed to this article.

Getting Creative in Science and Math

Professors work to open students' minds to the power of creativity

Name a creative person.

It's a good bet that the first person to come to mind is a painter, a dancer, a musician or perhaps a poet (unless the title of this article influenced you somehow). Are scientists and mathematicians creative at all?

In reality, creativity plays a huge role in the advancement of science and mathematics. Innovation, flexibility, inquisitiveness, open-mindedness – these are all traits that exemplify both creativity and mathematical or scientific thinking.

"A misconception is rampant out there that learning science and mathematics is only about memorizing, calculating, practicing and arriving at a predetermined correct answer," says Mika Munakata, a mathematics education professor. "So why do we encourage students to embrace creativity as they learn science and mathematics? We want to challenge students' preconceptions about the nature of science and mathematics."

Munakata and Physics Professor Ashuwin Vaidya are developing and assessing instructional units under a National Science Foundation – funded project titled Engaged Learning through Creativity in Science and Mathematics. Through these exercises, or modules, students ask questions, test assumptions, take on nonroutine approaches and find ways of personalizing their experiences.

For example, in a module on probability, finger paint and an inflatable globe that students can toss around are used to think about how to estimate a percentage of landmass on Earth. In this first year of the three-year project, Vaidya, Munakata and Ceire Monahan, a doctoral student in mathematics education, are testing and evaluating various modules.

Next year, Montclair State will roll out its Creativity in Math and Science (CMS) Scholars program, which will be open to all undergraduate students. This scholarship program will have students work in interdisciplinary teams pursuing a nontraditional research project designed to promote creativity in STEM.

"We want to put creativity at the center of the education process from early on," explains Vaidya. "Our hope is to create a network of science and math educators who are open to new ideas and different approaches – from middle school through college."

CMS Scholars, who will receive a modest stipend, will benefit from working with students from other disciplines and from personalized mentorship from faculty members and industry partners. Most importantly, the CMS students will gain research experience working through the lens of creativity – a highly sought-after trait these days.

For more information or to apply to be a CMS Scholar, please visit **montclair.edu/csam/mathematics-science-creativity**.

Professors Mika Munakata and Ashuwin Vaidya contributed to this article.

Mathematical Education Professor Mika Munakata (top left) and Physics Professor Ashuwin Vaidya (bottom right) lead a class in creativity in science and mathematics, teaching students how creativity shapes thinking and leads to better understanding and innovation.

Taking Geology to New Heights

Field camp gives student researchers hands-on experience in the Rocky Mountains

The view of Middle Teton (elevation 12,805 feet) as seen from the Garnet Canyon in Grand Teton National Park

In the study of the Earth, few places compare to geology field camp in the Rocky Mountains. A tradition in the education of geologists and geoscientists, geology field camp gives undergraduate students hands-on experience in the application of their classroom and laboratory education. The field camp course offered by the Montclair State Department of Earth and Environmental Studies (EAES) includes visits to the Beartooth Plateau in Montana and Yellowstone and Grand Teton National parks in Wyoming, as well as Stokes State Forest in New Jersey, exposing students to some of the best landscapes available to geologists when developing skills they need for future careers or graduate studies.

"The environment out West is perfect for field geology in the summer. The scenery is spectacular, the weather is perfect and we can lead students through field projects that start out simple and become more complex as we go along," says Matthew Gorring, an associate EAES professor.

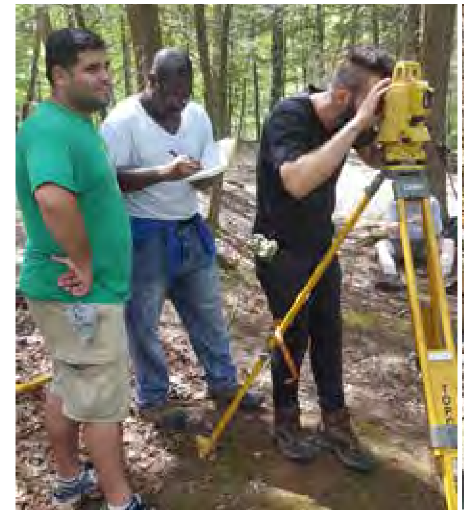
For a fourth consecutive year, students in EAES404 Field Geology and in EAES303 Field Geography applied their skills and knowledge for six weeks during the summer working in the field in an EAES summer field course. Each year, the field camp begins at the New Jersey School of Conservation, where, for the first two weeks, students focus on soil, geophysical and geomorphic skills to assess a hypothetical project of building cabins next to the local river. This summer, 12 students investigated the surface and subsurface characteristics using a variety of hydrologic and geophysical techniques including total station, flow meters, electrical resistivity and ground-penetrating radar. They submitted results of the project in the form of high-quality maps and profiles, a written summary report and an oral presentation.

For the last four weeks of the program, the students lived and worked in the Yellowstone region of Wyoming and Montana, where they conducted geologic mapping projects. Working in small teams, students identified and measured the orientation of different rock units and took detailed field notes.

Final products included geologic maps, stratigraphic and structural cross sections, and written summary reports. Each year, students also take a four-day tour of the Beartooth Plateau and Yellowstone and Grand Teton National parks. Highlights include Old Faithful Geyser and the Grand Prismatic Spring in Yellowstone, a 10-mile hike to the base of the Middle Teton Glacier in the Tetons and a whitewater raft trip down the Gallatin River near Bozeman, Montana. The last 10 days are spent at the University of Montana-Western in Dillon, Montana, where students conduct more complex mapping projects in order to apply all their newly learned field skills.

"It's definitely as much a life experience as an educational one," Gorring says. "The physical and mental aspects to this course can be difficult but the students do an excellent job of handling both."

Professors Matthew Gorring, Joshua Galster and Gregory Pope contributed to this article.



Top left: EAES majors Dominick Marrone, Victor Williams and Malek Ismail survey the research site at the New Jersey School of Conservation. Top right: 2017 Field Geology class at the Gypsum Creek site in Montana's Pryor Mountains. Bottom: Students mapping the complex geology at Block Mountain near Dillon, Montana.

Listening to the Universe

Scientists proving Einstein's theories usher in new field of gravitational-wave astronomy

Artist s depiction of the merger of two black holes and the gravitational waves that ripple outward as the black holes spiral toward each other. Inset: Marc Favata

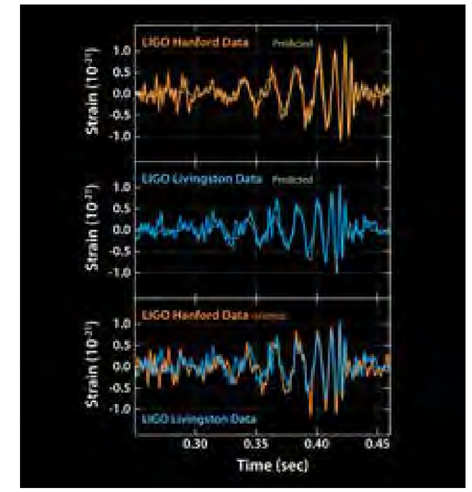
Image credit: LIGO/T. Pyle

Gravitational waves – ripples in the geometry of space and time – were first predicted by Albert Einstein in 1916. A century later – on September 14, 2015 – the first detection of a gravitational-wave signal, produced by the merger of two black holes, was made by a new instrument called LIGO. A second black hole binary merger was detected on Christmas of that year and a third was observed in January of 2017. These events mark the birth of a new field, gravitational-wave astronomy.

The Laser Interferometer Gravitational-wave Observatory (LIGO) is a $500 million, National Science Foundation-funded project consisting of 2.5-mile-long L-shaped interferometers separated by roughly 2,400 miles (one is located in Louisiana, the other in the state of Washington). Gravitational waves jiggle the mirrors at the ends of each "arm" of the interferometer by about 1/1000th of a proton diameter; when light from each arm is recombined, the resulting fluctuations in the interference pattern allow us to infer properties of what produced the waves.

As more black hole mergers are detected (we expect at least a few per year), we'll be able to answer some key questions: Did these black holes form in regions where the density of stars is low or high? How did those stars interact and evolve before they became black holes? Is Einstein right? Or does another theory of gravity provide a better fit to observations. The LIGO group at Montclair State is helping to make progress on these questions.

One important area of gravitational-wave research is producing better models of merging compact stars when their orbits are elliptical. Using these models, we can understand how well LIGO can constrain the ellipticity of a binary's orbit (which tells us about how the binary formed). We are also exploring how ellipticity can bias our measurements of the binary's masses and spins or contaminate our tests of Einstein's theory (by mimicking a different gravity theory). Another project explores a slowly varying component of the gravitational-wave signal called the "memory effect." This provides information about a nonlinear interaction in which gravitational waves themselves produce more waves. LIGO or future instruments should eventually observe this phenomenon.



Signal observed by each LIGO detector

Image Credit: Caltech/MIT/LIGO Lab

Our work at Montclair State is supported by a National Science Foundation CAREER grant and has involved students Kevin Chen, Lita de la Cruz, Matthew Karlson and recent graduates Goran Dojcinoski, Nicholas Drywa and Blake Moore. New faculty member Rodica Martin has also recently joined our group, bringing expertise in experimental optics. Along with the above projects, all students are involved in public outreach – including the development of **soundsofspacetime.org**, a website that explores the physics of gravitational waves via an analogy with sound (both easily penetrate dense regions and are produced by macroscopic motions as opposed to microscopic ones).

What is this all good for? Simply the "pleasure of finding things out" – understanding how nature works the way it does. LIGO provides the ears that let us perceive our universe in an entirely new way.

This article was written by Professor Marc Favata.

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Expanding for Science

A renovated Mallory Hall is scheduled to open in fall 2018.

Students returned to campus this fall to find the renovation of Mallory Hall in full swing. With completion anticipated by summer 2018 and occupancy set for that fall, the $22.2 million project will provide ideal new spaces for the rapidly growing instructional and research programs in computer science and information technology as well as other College of Science and Mathematics programs and services, including several specialized biology research laboratories.

"This facility will allow the state's second-largest university to sustain and grow high-quality, high-demand science programs that are directly aligned with the state's needs," says Lora Billings, acting dean of the College of Science and Mathematics.

When the 52-year-old building expands to 43,800 square feet with the addition of a fourth floor, it will include classrooms and laboratories, faculty offices, meeting rooms and student study spaces, as well as many specialized spaces for research in areas such as image processing and systems, parallel computing and computational sensing and optics.

The building will also be life-cycle renovated to include a new heating and cooling system; plumbing and electrical upgrades; life-safety systems replacement; environmental systems remediation; new flooring, ceilings and walls; and a new exterior façade to match the mission style of Schmitt Hall, which was its original sister building.

"Our programs focus on critical and core areas of STEM education," notes Billings. "To teach these areas in the 21st century, you need a 21st-century facility."