Biology

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The Amot Family of Proteins Binds and Activates Nedd4 Family Ligases to Promote the Ubiquitination of LATS and YAP

Amot adaptor proteins bind apical polarity and Hippo signaling proteins, which control cell growth and polarity. For instance, Amot proteins directly bind the Hippo signaling protein, YAP, which has a well-established role in activating transcription factors that control the expression of genes involved in organ homeostasis and cell growth. This interaction is mediated by conserved PY motifs found within Amot proteins that bind the WW domains in YAP. Prevention of nuclear accumulation of YAP by either sequestration or degradation in the cytosol abolishes its transcriptional functions. YAP is inhibited through phosphorylation by the Hippo kinase, LATS. Recently, binding by the Amot proteins was found to inhibit YAP by sequestering it in the cytosol through both LATS dependent and independent mechanisms. In order to investigate the signaling complexes associated with Amot proteins, their binding partners were identified. This revealed multiple associated Nedd4 family ubiquitin ligases, but the biological significance of these interactions are unknown. Nedd4 ligases contain multiple WW domains and their activity is often enhanced by binding proteins containing PY motifs.

Thus, the objective of this study was to determine the role of Amot proteins on Nedd4 ligase activation via auto- and substrate ubiquitination. These roles were examined by specific point mutations that ablated the PY motifs of the Amot proteins and the WW domains of Nedd4. Immunoprecipitation experiments showed that Amot proteins bind specific Nedd4 ligases endogenously. Such association was further found to be mediated through specific sets of WW domains in the ligase that bind PY motifs in each Amot protein. Amot proteins containing ablated PY motifs were found to lack the ability to bind Nedd4. Fluorescence-based imaging showed that exogenously expressed Amot proteins were able to redistribute Nedd4 to endosomal-like puncta. Because Nedd4 ligases are often auto-inhibited, the effect of binding Amot proteins on the Nedd4 activity was also measured. Wild-type Amot proteins, but not binding-defective P-Y mutants, induced the auto-ubiquitination of Nedd4 ligases, an event associated with Nedd4 activation. Further, such binding enhanced the ubiquitination of the previously reported substrate, LATS, and the novel substrate YAP. The observation that co-expression of Amot and Nedd4 synergistically increased YAP dependent transcription suggests that Amot also activates YAP by inducing its ubiquitination.

Pike High School students examined the correlations between the steady-state levels of YAP, Nedd4 and Amot proteins across epithelial cell lines. Taken together this work lays the foundation for understanding how localization and activation of Nedd4 ubiquitin ligases by Amot proteins may underlie their effects on growth control through the regulation of the Hippo pathway component YAP.

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Small Hive Beetle Attraction to Diverse Yeasts Growing on Pollen and Liquid Media

There is a rich diversity of yeasts present in microhabitats such as insect guts and pollen stores in beehives. The chemical ecology of these yeasts is largely unexplored. Experiments with oak wilt fungus and other slime flux-associated fungi have shown that the oak wilt fungus produces compounds that specifically attract its beetle vector. Recently identified yeast (*Kodamaea ohmeri*) associated with the small hive beetle appears to emit a similarly specific attractive volatile blend when growing on pollen. However, major attractants such as isopentyl acetate and 2-heptanone are common yeast metabolites. In this study, we compared the volatile production of 6 yeasts from various ecological and phylogenetic backgrounds, both beetle-associated and not beetle-associated, including K. ohmeri from the small hive beetle. The volatile profiles of these 6 yeasts were very similar to each other. Even the commonplace baking yeast

Saccharomyces cerevisiae produced significant quantities of beetle-attractant compounds when growing on pollen. Volatile profiles varied significantly with the kind of media that was used, either sabouraud dextrose broth or gamma-irradiated pollen. More volatile organic compounds and more complex blends of compounds were produced by yeasts grown on pollen than those grown on sabouraud dextrose broth. These results suggest that production of beetle-attractant volatiles is not specific to beetle-associated yeasts, but is largely dependent on the substrate. Adult small hive beetles were attracted to all of the yeasts. Yeasts growing on pollen where more attractive than yeasts growing on liquid media. These results may imply that the association between the small hive beetle and *K. ohmeri* is a weak association and that

the small hive beetle could form associations with many yeasts present on attractive substrates such as pollen.

I integrate my research into my 5th-grade classroom by stressing the importance of the unseen world--molecular, microbiological, and chemical. Lessons frequently include discussion of complex interactions between different organisms and their environment.

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Analysis of Digital Values From Multispectral Aerial Imagery to Assess Water Quality Parameters of Tibbee Creek in Clay County, Mississippi

Assessing water quality of impaired streams helps determine the type of impairment and identify the exact location where the impairment is most severe. Advances in remote sensing and geospatial technology have allowed researchers and environmental agencies to assess streams by monitoring large areas. Using both water quality measurements and digital number (DN) values extracted from aerial imagery, a relationship can be established to provide an accurate assessment of stream health. The goal of this study was to demonstrate the use of aerial imagery in detecting water quality indicators in impaired streams.

A 3-mile segment of Tibbee Creek in Clay County, Mississippi was selected for this study. Ten transects along Tibbee Creek were established and monitored, and water samples were collected from five points in each transect. Fifty water samples were collected per sampling date over two periods from May 2010 to October 2010 (14 sampling dates), and from May 2011 to October 2011 (11 sampling dates). The temperature differences and dissolved oxygen levels were measured at each point during both periods. Flow rate and depth were measured at each point only during the second period. Samples were tested in lab for turbidity levels and total suspended solid concentration (TSS). High resolution (0.5 m) aerial images that covered the entire study area were obtained in order to capture spatial differences along the channel. Coloring and reflectance issues were addressed prior to establishing a relationship between the digital number values and the experimental sample values. Preliminary analysis showed that turbidity readings were higher in the downstream segment of the river during the early part of testing and toward the end of testing. This was not the case during the middle of the summer and after rain events. Relationships between spectral bands and observed water quality parameters were used to estimate the water quality parameters at different locations of Tibbee Creek. The results of this research are expected to assist in the development of near real-time maps for the evaluation and monitoring of water quality of streams and rivers, providing large spatial coverage resulting in significant cost-savings over conventional *in situ* water quality and hyperspectral remote sensing.

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The Influence of Invasive Species on Native Diversity

The spread of invasive species is the second leading cause of biodiversity loss. Community assembly is the development of communities through the arrival of colonists from a regional species pool. I hypothesized that competition with invasive species will alter community assembly and development in marine sessile invertebrate communities, resulting in lower native diversity. I tested this hypothesis through an experimental design to examine the influences of competition with invasive species community assembly.

Marine sessile invertebrates are comprised of a group of organisms that have mobile larval stages and stationary adult life stages. Because of this, their larvae readily settle on hard substrate. Polyvinyl chloride (PVC) panels were deployed as hard substrate to collect the invertebrates. The PVC panels were divided into the following three treatment groups: 1) competition with invasive species 2) invasive species removal and 3) removal of and equal but random invertebrate biomass (control). Invasive species and control groups were manually manipulated on a biweekly interval.

I found that over time, competition with the invasive species decreased the diversity and richness of the native species able to settle and survive. Therefore, competition with invasive species decreased native species diversity in this system. The assembly of communities has implications for biodiversity and conservation decisions. Understanding the contributing forces to assembly, interactions between them, and how they are influenced is of critical importance. If invasive species are able to out-compete native species at such early time scales in the development of communities, the emphasis on invasive species abatement must be prevention of their transport.

This research was incorporated into the STEM program by exploring the main causes of biodiversity loss using the acronym HIPPO within an Environmental Science class. HIPPO stands for habitat destruction, invasive species, population, pollution, and overharvesting. Using my research, I developed a PowerPoint presentation so that

students were able to see how invasive species can influence the diversity of natural communities over short time scales. Students also learned what community assembly is, and how the natural communities that we observe around us develop. In addition, students learned to identify differences between native, non-native, and invasive species based on the environmental and/or economic threats that they pose. Students were also given exposure to experimental design in an ecological setting, stressing the importance of identifying a question, formulating hypotheses, and experimental treatments, including the definition of a "control" treatment, and how to interpret scientific results.

Biology-Geology

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Soil Erosion Rates and Water Quality In North Carolina

In North Carolina, excessive sedimentation in surface waters has been linked to urban and agricultural land uses resulting in habitat destruction and geomorphologic changes in rivers and streams (2). Erosional activities are reduced when soil is properly managed, such as the establishment of vegetative buffer zones along stream and river shorelines and crop rotation (3, 1).

The goal of my research is to develop a model that determines the main soil types found in the Cape Fear River Bain, North Carolina and their potential effects on the health of surface waters. Understanding the physical and spatial characteristics of soil types, including proximity to surface waters, varying land use activates, and erosion rates will assist researchers and policy makers in developing land use policies aimed at conserving soil and reducing sedimentation loads to surface waters in the Cape Fear River Basin, North Carolina.

Using the water quality parameter Turbidity (NTU), which is an indictor of cloudiness related to suspended solids, assessments are currently being made to understand spatial and physical variations in soil type, precipitation patterns, and turbidity found in surface waters throughout North Carolina. In addition, Digital Elevation Models (DEMs) will be included to incorporate topographical influences on surface runoff movement.

To investigate varying infiltration rates and soil saturation points, my third grade students were given back ground information about the physical characteristics of soils and how soil erosion and related sedimentation have affected surface waters in North Carolina. Definitions and examples were provided so students had a better understanding of terms and their real world applications. Students were asked to apply different amounts of water to three different soil types including clay, sand and topsoil. Students explored each soil through a microscope and by touching the soil, making note of its particle size, shape, and texture. Measuring tools were given to students who were directed to measure equal amounts of water and soil. Each type of soil was placed into different jars and students added water slowly, making note of the time and amount of water it took for a soil to become completely saturated.

Slower infiltration rates were observed for clay and topsoil compared with sand. The student concluded that the clay's small particle size and fine texture would make it more susceptible to erosion than topsoil and sand.

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(2) Lenat, D.R., and Crawford, J.K. 1994. Effects of Land Use on Water Quality and Aquatic Biota of Three North Carolina Piedmont Streams, Hydrobiologia 294: 185-199.
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Plant Molecular and Isotopic Indicators of Light Environment: A New Approach to Proxies for Canopied Ecosystems of the Past

Dense closed canopy forests of the tropics represent a large carbon reservoir (~40% of global terrestrial biomass) and can have pronounced effects on temperature and rainfall due to modification of atmospheric circulation, hydrologic cycling, and surface albedo. Their geologic history, however, is poorly understood. Fossil records do not often preserve leaf features or forest characteristics indicative of canopy coverage. This study seeks to identify isotopic and biochemical metrics that can signify a closed canopy forest and are preserved in the fossil record.

The most charismatic feature of a dense canopy is the extreme vertical light attenuation. Leaves exhibit strong physiological responses to light environment and these adaptations are recorded in biochemical leaf features. Using a canopy crane access system in Panama, we sampled leaves in the full diversity of light environments characteristic of a closed-canopy forest and typified the

biochemical and isotopic components of these leaves. Bulk leaf material express vertical enrichment and a ~10‰ range in carbon isotope composition (δ13C). A similarly sampled open canopy forest had only a 6‰ range in bulk leaf material. Isolated alkanes - a geologically recalcitrant plant wax component - express a ~16‰ range in the canopy forest. Deep shade leaves produce very distinctive highly 13C-depleted long chain alkanes. A more depleted δ13C reflects the lower rates of photosynthesis typical of a deeply shaded environment. These data, from both open and closed canopies, were combined in a computational model that uses vertical biomass allocation of canopy strata and leaf lifespan to predict the δ13C and molecular distribution of leaf litter and soil organic carbon arising from this canopy. This model also predicts the number of fossil leaves necessary to sample the isotopic range distinctive to closed-canopies. Ongoing work includes testing the model results by analyzing fossil leaves from paleofloral assemblages and using associated sediments from assemblages to test model estimation of molecular distribution and δ13C of *n*-alkanes. We intend to extend these tests into geologic substrates and time periods that can inform us of the response of canopied forests to hyperthermal (global warming) events.

Concepts easily transferred from this project into the classroom include the evolution of plant life, chromatography and solubility in separation of complex mixtures, and estimation of biodiversity in populations and the affect on ecosystems. In particular, we discuss the relationship between chlorophyll and the light regime of a plant. Classes can grow plants in variable light regimes and then quantify the amount of chlorophyll in leaves as proof of concept for understanding canopy physiology. Diversity estimates from the schoolyard or nearby parks can help students understand ecosystem viability and sustainability in familiar environments.

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Bringing STEM Climate Change Research into the Classroom

Currently, I am a Master's of Science candidate at Saint Joseph's University, studying with Dr. Clint Springer. All research in Dr. Springer's lab is involved with some aspect of global climate change. For my study I used the model plant, Arabidopsis thaliana, to learn about plant responses to predicted climate change. I specifically focused on isolating the genomic regions that control plant development, reproduction, and architecture in order to learn more about the ability of plants to respond to predicted increases in atmospheric carbon dioxide (CO2) concentrations. I examined changes in flowering time, silique (seed) number, and branching architecture of a set of recombinant inbred lines grown at elevated [CO2]. I then performed a quantitative trait loci (QTL) analysis to identify genomic regions involved in the observed responses. This is the first study to identify the regions of the A. thaliana genome that control altered plant growth characteristics. These discoveries will be useful in predicting how plants will respond to climate change as well as in informing crop breeding programs that seek to increase agricultural production in the future.

As a GK-12 Fellow, I am able to integrate some research topics and skills into several portions of the 2nd and 5th grade units taught in Geo-Kids LINKS program. For example, in the fall 2nd graders study the Earth as a system, learning about important cycles, such as weather, climate and the life cycles of plants and animals. In addition, they learn how plants interact with their environment. I have been able to incorporate pieces of my research, including environmental effects on plant flowering and changes in plant structure, into the lessons used in these elementary science classes. The fundamental concepts of my research are simplified in a manner that makes them accessible to the students, while at the same time adhering to the Pennsylvania science standards.

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Integrating Hydrology and Water Quality Analysis into 6th Grade Earth Science Classrooms

According to the United Nations Intergovernmental Panel on Climate Change (IPCC), projected increases in atmospheric temperatures are expected to alter regional precipitation patterns (i.e frequency and intensity), impact runoff and infiltration processes and increase evapotranspiration in Southern California. My research efforts involve developing innovative methods to examine how climate change will impact future water quality (sediment transport and contaminant concentration) and quantity (volume) within this large region. This research is important because we are interested in understanding how future climatic change will impact local water resources in a region that is expected to have an increase in water usage (due to population increases) and a decrease in imported water (due to climate impacts on sources).

In order to convey to my 6th grade students the importance of water conservation and clean water, I developed a lecture and lab series on hydrology and water quality. The first lecture discussed how local climate drives

the water cycle and that future changes to climate, population, and imported water may strain our local supply. Within the second lecture, we discussed point and non-point sources of pollution and identified specific urban contaminants (i.e detergents, bleach, gasoline, animal feces, etc). Students were then asked to become student researchers for the Environmental Protection Agency and were required to perform water quality analysis on two "contaminated" field sites located within the Ballona watershed that feds directly into the Marina Del Rey embayment. This project allowed the students to identify with their local environment and grasp the importance of their work. Students were divided into groups and performed five water quality tests using field sampling kits on each site: pH, ammonia, phosphorous, chlorine and turbidity. Using their results and the prior knowledge from previous lectures, the students were asked to identify which site(s) were contaminated and write a strong letter to the business responsible for contaminating Marina Del Rey. The incorporation of this lesson module fulfilled their hands-on, minds-on Chemistry of Living Systems curriculum requirement.

Computer & Information Science

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Expanding the Point - Automatic Enlargement of Presentation Video Elements

We present a system that assists users in viewing videos of lectures on small screen devices, such as cell phones. It automatically identifies semantic units on the slides, such as bullets, groups of bullets, and images. As the participant views the lecture, the system magnifies the appropriate semantic unit while it is the focus of the discussion. The system makes this decision based on cues from laser pointer gestures and spoken words that are read off the slide. It then magnifies the semantic element using the slide image and the homography between the slide image and the video frame. Experiments suggest that the semantic units of laser-based events identified by our algorithm closely match those identified by humans. In the case of identifying bullets through spoken words, results are more limited but are a good starting point for more complex methods. Finally, we show that this kind of magnification has potential for improving learning of technical content from video lectures when the resolution of the video is limited, such as when being viewed on hand held devices.

In the classroom, such as an Algebra II class, we discuss the tools necessary to find when laser lines intersect with semantic units (e.g. finding the point of intersection between lines). For the more advanced students, such as Calculus students, we discuss some techniques of how to find a line given noisy data (e.g. linear regression) and how derivatives can help to find the optimal line.

Engineering

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Active Load Control for Wind Turbine Blades

Wind energy is providing a rapidly-growing portion of the energy we use, as wind turbines are recognized as a clean and affordable method of energy production. Increasing the size of wind turbines helps to reduce the cost of energy, particularly in sub-optimal sites for wind generation. The larger size of turbine rotors has led to increased loads on the blades, creating a need for novel methods of load control. My research examines two devices—microtabs and microjets—that have been proposed to control loads by rapidly adjusting the aerodynamic properties of the blade section in response to changing wind conditions. While the two devices are physically very different-- microtabs are an electro-mechanical system and microjets utilize compressed air-- their aerodynamic effects are similar. The two devices are being tested in the UC Davis Aeronautical Wind Tunnel using an airfoil model with a removable tail section that allows for the installation of different load control mechanisms. Both systems are being tested under conditions of changing wind speed and model orientation that simulate gusts of wind. Initial tests have been conducted with both load control devices. Microtabs were found to be able to mitigate gusts of wind up to ten miles per hour. Microjets were also shown to affect loads on an airfoil, while ongoing tests will examine dynamic behavior.

I am bringing my research into sixth grade classrooms in Sacramento as a part of the UC Davis RESOURCE GK-12 program. The curriculum begins by introducing basic concepts related to energy, such as heat and electricity. Hands-on activities, including solar ovens and handmade electric generators, help bring these concepts to life for students. Environmental impacts and the difference between renewable and non-renewable resources are also a part of the curriculum. Wind turbine aerodynamics are

introduced with activities including an investigation of the wind resource in the schoolyard and a blade design project using a small model turbine.

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Novel Polymer Blends for Holographically Dispersed Polymer Liquid Crystal Bragg Gratings

Holographically formed polymer dispersed liquid crystal (HPDLC) thin films are switchable Bragg grating films that have applications in remote sensors, fiber optics, reflective displays, light projection and optical beam steering. In this work, we demonstrate a blended oligomer base used to create optically enhanced HPDLC films. This research also includes material formulations optimized for the K-12 educational environment with examples of implementation in hands-on activities in a GK-12 chemistry classroom in inner city Philadelphia, a high school in the Kenyan highlands, and additional university-sponsored STEM outreach programs in the Philadelphia area.

In order to create HPDLC thin films, a pre-polymer blend of oligomers, liquid crystals and photosensitive laser dyes are placed between layers of conductive glass and exposed to a holographic pattern. The resultant lamellar structure of polymer and liquid crystal passively reflects a specific optical wavelength. The introduction of an electric field modulates the film from reflective to clear, including access to gray-scale levels. In this work, a novel blend of thiol-ene and acrylate oligomers were used. Resultant films were examined using Scanning Electron Microscopy and Shack Hartmann Wavefront Analysis (using Zernike polynomials to examine optical aberrant behavior characteristic of film structure). Optical and electrical switching behavior was determined with the use of a HeNe laser, photodiode, AC sourcemeter and amplifier, and an Ocean Optics NIR-UV-Vis optical spectrometer. The resultant hybrid films were optically superior (50% average diffraction efficiency) to the original acrylate (25%) and thiol-ene formulations (34%). Hybrid films featured a lower full width half max transmission profile and the Zernike coefficients of the optical thin films demonstrated fewer optical aberrations due to polymer structure.

When broken down into the fundamental science and engineering techniques of holography, polymerization, and liquid crystals, HPDLCs provide an excellent source for discussion and activity at the high school level. Modules were developed with a focus on the NAE Grand Challenges for Engineering. An understanding of the atom, electromagnetic spectrum and transmission lines was strengthened through hands-on holography and a discussion of optical detection of nuclear materials. A laboratory on optical polymerization provided insight into chemical reactions, covalent bonding and intermolecular forces. A laboratory with liquid crystal thermometers gave students awareness of states of matter and their role in solar energy applications. All modules and others were integrated into the classroom curriculum of schools in Philadelphia and Kenya using a subway map curriculum visualization tool and cross-cultural video-conferencing to ensure student accessibility and social context.

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Investigating Potential Biases in Observed and Modeled Metrics of Aerosol-Cloud-Precipitation Interactions

Aerosols are microscopic solid or liquid particles suspended in air. They are ubiquitous in the atmosphere and influence society and the environment in many ways: they are components of smog and air pollution, thus impacting public health. They influence global climate by interacting with solar radiation and the hydrologic cycle, and also impact the effectiveness of harvesting of solar energy. Sources of atmospheric aerosols include anthropogenic emissions (such as exhausts from cars or industry) and natural processes such as volcanoes and direct emissions of soil dust, sea spray, and biological particles. Aerosols range in diameter from nanometers to micrometers (close to the thickness of a human hair), making them small enough to be breathed in and penetrate deep into lung where they can cause short- and long-term health effects such as asthma, cardio-respiratory disease, and lung cancer. In addition, aerosols can reduce visibility by absorbing and reflecting sunlight, an effect which is particularly evident in the smog of major urban centers such as Los Angeles, London, Kuala Lumpur, and Mexico City. Not only do particles dim solar radiation by directly absorbing and reflecting light, but they indirectly influence climate by serving as cloud condensation nuclei (CCN), or in other words, acting as the seeds for cloud droplets. Conditions of greater pollution result in an increase in aerosol particles and more numerous, but smaller droplets, which increases the reflectivity of clouds. Furthermore, the collision-coalescence efficiency (the ability of small cloud droplets to collide and merge into larger drops, a critical process for producing raindrops) between these smaller droplets is significantly reduced, thereby suppressing precipitation.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007) indicated that the anthropogenic radiative forcing on climate associated with aerosol effects on clouds (the so called “cloud-albedo

effect") currently represents the largest uncertainty in estimates of future climate change. Such estimates are provided by general circulation models (GCMs), which represent physical processes relating aerosols, clouds, and precipitation by highly uncertain parameterizations. My research combines large eddy simulation, aircraft measurements, and satellite observations to identify factors that bias the results of GCM parameterizations of aerosol-cloud-precipitation interactions for warm clouds. The metrics considered are precipitation susceptibility S_o, which examines the rain rate sensitivity to changes in drop number, and a cloud-precipitation metric, *X*, which relates changes in rain rate to those in drop size. *X* and S_o are relatively insensitive to the growth phase (cloud lifetime) of the cloud for large datasets. Spatial resolution of measurements is shown to both influence the magnitude (suppression over larger scales) and the behavior of *X* and S_o as a function of cloud liquid water content. Other factors shown to be of importance include the aerosol proxy entering the model, drop size, and the method of quantifying rain rate. Depending on the use of model, satellite, surface, or aircraft data, these biasing factors will have different levels of impact.

The basic concept of the research was integrated into a high school classroom. The main objectives for this project were to introduce the students to my research and the concepts of the scientific method. At the beginning, I asked the students several simple research questions. For example: how does the cloud drop radius change with amount of water in the cloud? Then I gave them background knowledge about aerosol particles, clouds, and impacts of aerosols. Time permitting, the students researched more information on the internet. After learning the background, the students formulated hypotheses for each of the questions that were asked earlier. The students were then given a set of satellite data to analyze on excel software. This allowed the students, most of who didn't know about the software, to learn and practice excel. Finally, the students verified or falsified their hypothesis based on the results from the analysis. The students also gave explanations of the results, and then reported their conclusions. At the end of the project, students were able to learn about my research, how to approach research questions through the scientific method, and improve their excel skills.

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Brain Computer Interface & Chemical Bonding in 9th Grade Integrated Science

Brain-Computer Interface is a relatively new technology bridging several engineering fields with cutting-edge medical research. BCI seeks to resolve how thoughts, memories, and actions are represented in the brain, and leverage that knowledge in medical diagnoses, prosthetics, biotechnology, and new applications, such as sensory augmentation.

Currently, the field of BCI is limited to recording and analyzing output from the brain. While there has been extensive study on single-neuron firing and brain slices, the most applicable data is from a living, functioning brain. There are three main methods for in vivo recording: EEG, ECoG, and microelectrode arrays. Microelectrode arrays have very high resolution, but are the most invasive approach and often give too close of a view to see the whole picture. Electroencephalogram, or EEG, is a non-invasive, outpatient procedure where the electrodes are placed on the scalp. It gives a broad but blurry picture of the brain's activities. Electrocorticogram, or ECoG, rests in the middle of the previous two options; it requires a less invasive form of brain surgery, and the electrodes rest on the surface of the brain. This gives a fuller picture than electrode arrays at a much higher resolution than EEG. For patients that need brain surgery anyway, neural recording using ECoG is optimum, but clearly, for most BCI applications, EEG is the standard.

My current work in this field involves CUDA, a C extension, to do massively parallel signal processing for real-time spike sorting and analysis. This will allow for more EEG signals to be processed simultaneously and with very little lag, effectively creating a better real-time interface for BCI applications.

I demonstrated the Emotiv Epoc and some of its packaged software in a ninth grade integrated science classroom. I started a discussion about what the EEG device measured, which led to discussing what conducts charge in the brain. From this platform, I introduced them to ions. My lesson covered ion formation, the octet rule, and ionic, covalent, and metallic bonding. The bonding lesson involved the students taking the role of atoms and interacting with each other based on the number of valence electrons they had. Each student was assigned an element and given a number of beads corresponding to their valence electrons.

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Comparison of Novel CO2 Conversion Catalysts

Sodium carbonate catalysts supported by a high surface area coal or biomass char are being studied independently

in a plug flow reactor under different conditions including catalyst loading capacities and temperatures to determine the optimum conditions for CO2 conversion to CO ($CO_2 + C \rightarrow 2CO$). A pure CO2 gas stream is used for tests and the concentrations of the gases prior to and after the conversion process are measured using a gas chromatograph.

The purpose of this study was to convert the increasingly concerning gas, CO2, to a useful gas, CO, for energy production or organic chemicals synthesis. For example, the converted CO can be used for H2 production through the water gas shift reaction, which could create a win-win situation from the viewpoint of the energy production and environmental protection industries.

This research is being integrated into the K-12 classroom through GK-12 Fellows' field trips to K-12 schools and K-12 teachers and students' visits at University of Wyoming nano research labs where the students participate in the activities associated with the $CO_2 + C \rightarrow 2CO$ conversion technologies for clean energy production. They work with NSF Fellows to do on-site catalyst preparation. Through the use of safe hands-on activities and fun lab tours, K-12 students learn how fun STEM fields are and why they are so important to their own and the country's futures.

Another way we are transferring energy-environment related technology (EE-technologies) research to K-12 classrooms is through problem-solving. Problems have been developed by Fellows, which are related to the challenges we are facing and the impacts of their solutions on the real world, and understandable to K-12 students. K-12 students are induced to analyze a problem in EE-technology areas and solve it in a step-by-step manner. K-12 teachers and students will realize the importance of EE-technologies while Fellows highlight their benefits.

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Magnetic Resonance Guided Optical Spectroscopy Imaging of Human Breast Cancer

A breast contrast-MR scan is recommended each year to high-risk women because of MR's high sensitivity to breast tumors. However, breast contrast-MR yields a high number of false positives and leads to expensive MR-guided biopsy procedures. Therefore, there is a growing need for superior biomarkers derived from the lesion during the MR scan, so that the high sensitivity can be matched by a high specificity. We use a Near-Infrared Spectroscopy (NIRS) to augment MR information by providing information about blood content, blood oxygen saturation, water, fat, and scatter components. This functional information has been shown to provide information about tumor malignancy; however, optical imaging's low spatial resolution has limited its usefulness. An instrument that combines MR with NIRS has been developed at Dartmouth to non-invasively image high-contrast intrinsic properties of malignant breast lesions. The best performance in detecting breast lesions is likely to be found by combining these two imaging modalities to couple the strengths of each into one patient exam, and we hypothesize that we will be able to distinguish malignant from benign lesions with statistical significance.

This project has focused on improving the design and performance of the MR-guided NIRS system. Optical fibers are coupled into an MRI breast biopsy system and focus on 3D imaging. Tumors will be characterized based on more accurate measurements from the entire breast volume, which is vital to provide accurate quantification. Tissue-simulating phantom work has been shown to recover total hemoglobin levels to within 10% of the correct value. This technology has been demonstrated extensively in healthy human populations. Preliminary results in cancer patients are promising and we expect to improve the specificity of clinical MR-imaging by adding functional information obtained from NIRS.

Optimizing a multi-modality device and bringing it into the clinic requires being able to apply engineering and design thinking to problems in optics and light. This collaborative study has prepared me well to co-teach a course on design at The Sharon Academy Middle School as part of Dartmouth's GK-12 program. We have implemented my expertise in a supplemental course for 7th and 8th graders that focuses on problem solving using inquiry science and creativity in the classroom. We have used this year to allow students an environment to deepen their understanding of the scientific method and bridge the gap between the scientific method and engineering methodology. The year is culminating in a design project where students will complete short assignments to give them intuition and hands-on experience with optics and light energy, and finally assimilate information to design and construct solar cookers. The GK-12 program has made a fun and challenging environment for me (and my students) to develop as the year progresses.

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Integration of Wheelchair Biomechanics Research in a Lesson on Slope

Due to lower limb paralysis, many individuals with spinal cord injury (SCI) are forced to rely extensively on their upper limbs for mobility. The repeated performance of upper limb weight-bearing activities like manual wheelchair propulsion places a great stress on the structure of the shoulder complex, placing them at significant risk for overuse and injury. Investigators have used biomechanical techniques to identify potential factors contributing to shoulder pain and injury in persons with SCI. Recently, they have included computer graphics-based models with their techniques. The advantages include the ability to build patient-specific models and visualize profiles of movement. A limitation in this area of research is that few studies have evaluated individuals with tetraplegia (formerly quadriplegia). A computer graphics-based model of the shoulder has been developed, using OpenSim software, to generate dynamic simulations of wheelchair propulsion. Kinematic, kinetic, and fine wire electromyography data are being used to assess the model's ability to quantify individual shoulder muscle forces during wheelchair propulsion.

Aspects of this research were integrated in a lesson on slope for students in high school geometry and honors algebra classes. An enrichment activity about slope and wheelchair ramps was conducted. To introduce wheelchair ramps, the students were asked how they entered the school building that morning and how their method would change if they were in a wheelchair. After asking them what must be considered to design a wheelchair ramp, they recognized that the components of a wheelchair ramp form a right triangle and that the slope could be determined by finding the ratio of ramp height to ramp length. The students then learned about Title III of the Americans with Disabilities Act, which explicitly states the maximum slope for wheelchair ramps. To further demonstrate this, a simulation was made with Algodoo software where a person in a wheelchair tried to propel up two different ramps (only one ramp was in compliance with Title III). An additional Algodoo scene was developed to recreate the ramps as right triangles with given coordinates so that the students could determine the slope of each ramp. Upon doing so, they were able to prove that one ramp was steeper than the other and it was not compliant with Title III. To assess understanding of the lesson, the students answered a series of questions with the CPS clicker software.

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Circulating Tumor Cell Isolation and Analysis with GEDI Microdevices

Patients suffering from cancer shed tumor cells into the bloodstream, leading to one of the most important mechanisms of cancer spreading: metastasis. As such, the capture and study of these cells is of interest for cancer prevention and patient-specific treatment. Finding and extracting cancer cells from blood is difficult as they are incredibly rare (about one cell out of every billion cells is a circulating tumor cell, or CTC). These cells come from epithelial tissues, that is the linings of cavities, organs, and glands, whereas other cells in circulation do not. CTCs are typically extracted from circulation by using an antibody to target an epithelial protein, called EpCAM, that is expressed on a CTC's surface. Selecting antibodies that bind to EpCAM results in many CTCs not being captured as populations of CTCs undergo a process that causes them to downregulate EpCAM expression. This is unacceptable as CTCs are an already rare population; therefore other targets for cell binding must be determined. This is a difficult task as these targets are unique for different cancers. For example, in prostate cancer, prostate-specific membrane antigen (PSMA) presents a compelling target for capture, as PSMA levels increase in higher-grade cancers and metastatic disease. We have isolated CTCs from cancer patient blood samples using a novel technology called Geometrically Enhanced Differential Immunocapture (GEDI) microdevices. GEDI devices exploit differences in cell sizes and protein expression to capture more pure populations of CTCs in greater numbers (as compared to other techniques). This approach also enables the study of various aspects of cancer including chemotherapeutic efficacy, genomic analysis, and cancer biology.

The design and fabrication of microfluidic devices, a study of cancer biology, and the intersection of physical sciences and biology to work toward understanding and treating cancer were all explored by participating students in the classroom. Students engage with this material through a series labs, case studies, and interactive lessons. Labs include engineering design and multiple microdevice fabrication techniques. Case studies involve students in making decisions about treatment plans based on real patient data derived from GEDI microdevices. Lessons inform students about the physics, chemistry, biology, engineering, and medicine behind these investigations. These are ongoing areas of work both with the students and in the lab.

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Recombinant Spider Silk Proteins for Tissue Engineering Applications

The world of biomaterials is a rapidly changing field. The quest for the next generation material that can replace the current standard is a never-ending search. In my research we are focused on creating tissue engineering scaffolds for wound healing applications using synthetic spider silk proteins created in *Escherichia coli*. Spider silk is a material that has been shown to have tremendous mechanical properties such as tensile strength and elasticity. By weight, spider silk is even stronger than steel and on the same order as the world's strongest man-made material Kevlar. Spider silk has been shown to be relatively inert in in-vitro studies with little to no immune response, which greatly reduces the possibility of rejection if used as a biomaterial.

Using recombinant spider silk proteins, we are able to form nanofibers by electrospinning. Electrospinning involves dissolving the protein in a solvent with high volatility. The solvent is then placed in a syringe pump where the needle is charged with high voltage ranging form 5-30kV. At high voltage the protein spontaneously forms fibers in order to dissipate the charge and are attracted to a grounded or negatively charged collector plate. These nanofibers can be modified with small peptides that are recognized by cells as binding sites to attach, grow, and proliferate. Cell adhesion is an important aspect of growing new tissues because binding of cells by receptors called integrins, triggers intracellular signaling necessary for cell survival.

This work focuses not only on creating scaffolds to grow new tissues, but also on the mechanical properties of the silk scaffold so that it closely recapitulates the properties of the tissue it is replacing. The mechanical properties of the electrospin nanofibers are closely related to the concentration of protein in the spin solution as well as other additives that are used to control alignment of the protein and charge during spinning.

The spider silk used in these studies is created using transformed bacteria and is a prime example of genetic engineering. Gathering spider silk from spiders is impractical due to the small amount they produce. The gene for spider silk is transferred to *E. coli* where it can then be produced. To demonstrate the ability to transfer genes from one organism to another, we can preform a similar transformation in the classroom. Students get to transform *E. coli* with a small piece of DNA that contains the gene for the same fluorescent protein found in jellyfish. This lab teaches students the benefit of gene transference and gives them a visual proof of transformation with a physical change. Students also learn valuable laboratory skills and practice using sterile technique.

Engineering / Computer and Information Science

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Bringing Robotics to the High School Level

Robotic engineers must understand how to assemble a robot and how to write algorithms that control a robot's movement. The more accurate or complex the movement required of the robot typically implies more powerful computers and larger batteries. Both of which will increase the size and cost of the robot. My research focuses on simplifying these algorithms to work on cheaper computers and to use less power while maintaining similar performance. Such advances will enable robotic devices to be made smaller, cheaper, and more power efficient.

To bring my research into the classroom, biology and physiology students were exposed to electronics when tasked to build their own heart rate monitors. A basic heart rate monitor requires an infrared light be shown on their finger. Oxygenated blood being pumped through the finger changes its reflectivity to infrared light as it is pushed periodically through the finger. Using an infrared sensor, this periodically reflected light is detected and then triggers a red light which enables a visual means of measuring a patient's heart rate. The electronics is used as a vehicle for exploring how physics can be combined with physiology to produce useful medical devices. This lesson combines CA Science Standards Physics 4e and Biology 9a.

For the robotics club students who are already interested in engineering and robotics, having a graduate student mentor in engineering proves to be an invaluable resource for explaining the differences in each engineering discipline as well as possible future careers in each discipline. Small projects, such as a bicycle generator project, are introduced to act as quick projects to allow students to gain some engineering experience and to give the students an immediate sense of accomplishment. Aside from their robotics competition, students can use these projects to act as magnets for new members and as catalysts for grants to fund future projects. Projects for the robotics club cover CA Science Standards' Physics 5a and 5f.

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Cognitive Database for Information and Knowledge Sharing through Bayesian Networks

Through the last decade, robots have become better at wide varieties of tasks requiring accurate recognition, from face detection to folding towels. Still, many successful robots have a difficult time when seeing objects from multiple orientations or with partial occlusions. This is because the robots are not perceiving but blindly attempting to match what it sees to everything it knows. Also most of these robots are unable to share information or gathered experiences thus making it next to impossible to coordinate or collaborate between different robots. Currently, each robot or system is very good at specific tasks (e.g. face recognition) but ill suited for others (finding doors). We introduce our cognitive database as a method to share information and teach robots to define and understand what it sees cognitively.

Previous work by others has demonstrated the success of part based recognition. We expand on this by decomposing objects into common concepts such that it can be translated easily between multiple different robots. This allows robots to communicate not with numbers and symbols but with concepts like “red,” “circle,” etc. For example, a person is partially covered by a parked car as they cross the road, the robot detects the person before they jay walk across the road. A robot is searching for a missing child in a crowd, the robot communicates with other robots to coordinate the search effort to find the missing child.

Our implementation, the Cognitive Database, knowledge and relationships are stored in a modified Bayesian Network that can create new nodes with uncertain priori probabilities. The Cognitive Database allows us to not only introduce additional descriptors of knowledge (such as color, location, shape) but also bypass the problem of new classes through the introduction of a null class, where uncertain or unverified knowledge is stored until validation. This semi-supervised model allows for self-learning in the unsupervised state while allowing for correction, validation, and labeling to be done by a supervisor. This model is similar to the model for learning for humans, where individual are left to learn autonomously until uncertainty requires the individual to refer to outside help for clarifications. Individual robots would be able to communicate information about higher level concepts such as objects by description. This would allow robots to freely disseminate knowledge about objects with each other without having to re-evaluate or re-experience the concept.

We modify the implementation of Bayesian Network to include the null class, in which objects that have a recognition confidence below a set threshold would be added. We mainly focus on three descriptors, colors, shape and spatial location but also use more advanced feature descriptors such as HOG (Histogram of Oriented Gradients). These input features are mapped to labeled groups such as “red” for colors, “circular” for shapes, and “floor” for spatial locations, we mainly focus on features that are easily described. The features are then mapped to object components, which are then utilized to define complete objects by building them from parts. The sample task for the database to identify and describe is people in regular environments. As our focus was mainly on the viability of the new implementation as a method to share knowledge, we did not emphasis improving the recognition rate in our project. The overall improvement in recognition rate was approximately 0.9%, which may be due to factors between the complexities of our model compared to other recognition systems. Currently we have proposed that we simplify the base recognition model to verify if complexity is a contributing factor.

The cognitive database could eventually be developed to resemble how people share information today. Robots could request information to improve their understanding through a reference system, another robot and possibly even a human being. This would allow simplification in communication for humans and robots for recognition and detection. The relationships found by examining the Bayesian Network could also further provide unknown insight into relationships between features, and possibly into human cognition on knowledge representation. We may find that certain feature descriptors, such as color, is irrelevant in identifying certain object groups, even though conventional wisdom would contradict it.

While we have not been able to integrate the middle school students directly into our research, we have had success in introducing the major concept present in the research topic to the students. With the students in the robotics club we have had time to discuss the philosophical, economical, and political implications of creating a generalist artificial intelligence that can conduct most of our daily tasks. They have been introduced to advanced concepts in computer vision, and types of learning. The students were also mentored for the First Lego League, as their presentation about the possibilities of robotics in the field of medicine, civil engineering, and environmental engineering.

Geology

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Bahamas Stalagmites: Archives of Past Climate Variability*

Stalagmites have been collected from currently submerged caves in the Bahamas. These caves are locally known as "Blue Holes" and the stalagmites are collected using advanced diving technologies at depths ranging from 10-40 meters below sea level. The stalagmites form when sea level is low and the cave is exposed to air. Stalagmites are analyzed for their geochemical signature which preserves records of past climate variability. During the last glacial period there is substantial evidence for global variability in climate dominated by Heinrich events. Heinrich events have been shown to correlate with rapid climate change such as cooling in the North Atlantic, precipitation decrease in Africa and Asia and warming in Antarctica. While a comprehensive picture of climate patterns is emerging, the climate in the topical Atlantic is still not well understood. In this study, a stalagmite from the Bahamas has been analyzed for carbon and oxygen isotopes, fluid inclusion isotopes and trace element analysis across Heinrich events 1-3. The combination of these methods allow for the determination of the water isotopic variability and the temperature at the time of formation, both of which are important for understanding climate in the Bahamas.

To date, over 15 stalagmites have been collected and dated using U/Th. Stable carbon and oxygen isotope analysis and trace element analysis was conducted at a resolution of 20 µm (approximately one sample every 2 years). Carbon and oxygen isotope analysis of carbonates relies on the determination of the ratio of 13C/12C and 18O/16O of the sample relative to a standard. In the subtropics, it has been demonstrated that higher volume rainfall events generally leads to a deplete δ18O and δ13C signal, whereas heavier δ18O and δ13C values are attributed to lower amounts of rainfall. Fluid inclusion analysis is the analysis of microscopic, water filled cavities within the stalagmite. These cavities preserve drip water at the time of formation and allow for the direct measurement of the δ18O composition of the formation water. Therefore, by measuring the fluid inclusion isotopic composition a better understanding of past precipitation changes can be determined. Additionally by combing fluid inclusion and the carbonate isotopic data, temperature at the time of formation can be determined.

The carbon and oxygen isotope data from the carbonate demonstrate significant shifts associated with Heinrich events 1-3. Across all Heinrich events, carbon and oxygen isotopes increase leading into the events followed by a rapid decrease after the events. The shift on average is about 4‰ for carbon and 2‰ for oxygen for Heinrich events 1-3. The fluid inclusion data help constrain the origin of the large changes in the oxygen isotopic composition of the speleothem calcite across the Heinrich events. These results support a rapid shift from an arid and colder to a much wetter and warmer climate in the Bahamas associated with Heinrich events. Additionally associated with Heinrich events, trace element data demonstrate an increase in the iron concentration of the speleothem of up to 600 ppm. Outside of the Heinrich events, concentrations remain relatively low at approximately 50 ppm. Since the Bahamas is relatively free of iron, the iron is thought to be derived from African dust being transported across the Atlantic and deposited in the Bahamas. It has been well documented that Western Africa is arid during Heinrich events, therefore providing a source of dust. The increase in dust has implications for the climate system and potentially dust may act as an important feedback or as a forcing of such climate change events of the past.

The research presented above is successfully incorporated into the classroom to cover topics on chemical weathering. To begin, students were engaged and introduced to the research through the NOVA video "Extreme Cave Diving." Produced in 2010, this video introduces chemical weathering, the process which leads to the formation of the caves in the Bahamas. This video also introduces the cave environment, the features formed within caves and the process by which the cave features form.
Students then explore the question, how do sinkholes form? Students explore chemical weathering by making their own sinkholes, features found throughout Florida. Students create their sinkholes by using chalk and building their bedrock with it. Weak acid is then dropped on their bedrock for several days using a burette and students observe the changes in their bedrock by measuring the size and shape of their sinkhole over a few days. Students then explain their observations in the context of chemical weathering. Students compare their model to the natural world by comparing their sinkholes to sinkholes in Florida using Google Earth. Students use Google Earth to measure the size and shape of sinkholes in Florida and to map the location of sinkholes. As an elaboration, students then create a newscast video to be shown in class about sinkholes in Florida using their model sinkholes in their newscast.

As an extension, for those who have difficulty understanding the process of chemical weathering, students are engaged by looking at photos of the effects of

chemical weathering on statues and landforms. Students then explore chemical weathering by being given various types of rocks including limestone, chalk and granite and begin by determining the mass of the samples. Students then place the rocks in different solutions (some weak acids, some basic) and collect data on how the rock reacts with the solution by making observations. This is followed by the students finding the mass of the rocks after placing them in the solution. Students are assessed by representing their data in charts and drawings of their observations.

To integrate into the classroom more on the cave environment, a cave model of Epson salts allows for students to explore how stalactites and stalagmites form. This model allows for the demonstration of the types of features found in the cave environment (i.e. stalagmites and stalactites) and the observation of how these features form in the cave. Students collect data on the model by measuring daily the height of their stalagmites and stalactites and calculate growth rates. Student assessment is through drawings of the cave features and presenting their data on cave growth rate. Students additionally make inferences on what factors influence the growth of their stalagmites and stalactites. To elaborate on this topic, students then research caves in Florida and human impact on caves, as they are fragile environments.

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A Fieldtrip Through Earth's Existence

Rocks that at one time were part of the lower crust are important to our understanding of the formation of continental crust, but can be difficult to study because they are not commonly exposed at the Earth's surface. However, in some locations, magmas have entrained lower crustal rocks as they moved through the crust and emplaced the lower crustal rocks close to or at the surface where they are accessible to scientists. The entrained rocks are called xenoliths, and in the Eastern Snake River Plain (ESRP) of Idaho, xenoliths provide the only window into the lower crust of the region. In this study, xenoliths were collected from the ESRP at Spencer-Kilgore (SK), Craters of the Moon National Monument and Preserve (CRMO), and Square Mountain (SM) in Fairfield to investigate the age of formation of continental crust in southeastern Idaho, as well as the modifications to the crust during the Precambrian (4600 Ma - 542 Ma). Zircon minerals were separated out of the xenoliths and dated using Lazer Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) U/Pb geochronology. Dates were correlated to zones of growth in the zircons imaged using cathodoluminescence. Ages of growth zones from SK and CRMO indicate crustal formation in the eastern part of the ESRP is at least as old as 3.2 Ga and could be as old as 3.7 Ga, and that the SK and CRMO regions shared a metamorphic history during the Precambrian. SM has proved to be a distinct region from SK and CRMO, with crust at least as old as 2.6 Ga.

The ancient Precambrian lower crust of Idaho has inspired a fieldtrip lesson for the 4th, 5th, and 6th grades on the geologic timescale implemented at the Foothills Learning Center in Boise as part of the Boise State University GK-12 program. In the first part of the lesson, students choose a milestone in Earth's history to represent and calculate where on a 100-foot timeline of Earth's existence his or her milestone is located. Students arrange themselves on the timeline and discuss the distribution of students and what the distribution means in terms of changes on Earth. In a second activity, students act as geologists by investigating rock layers of the foothills to discover the order of events that formed the rocks. In the final part of the lesson, students become a human model of radiogenic atoms in a rock to learn about radioactive decay and the part it plays in how scientists date rocks. This lesson integrates science, math, and the outdoors to educate students about geologic time.

Mathematics and Physical Science

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Study of Fractal Aggregates Using Small Angle Light Scattering

Colloids and aerosols are examples of nanoparticle systems which are common in natural and anthropogenic environments with fractal aggregation characteristics. A light scattering technique is used in this study to measure the size and aggregation kinetics of small particles. A 633 nm He-Ne laser was applied to illuminate the sample, and the scattered light intensity was collected as a function of angle using a photodiode array. The current experiment aims to study the aggregation kinetics of 20 nm polystyrene latex spheres under $MgCl_2$ induced aggregation which screens the polystyrene repulsive interaction. Irreversible aggregation creates structures

with 1.83 +/- 0.07 fractal dimension (Df), which eventually fill the entire system volume to form a gel. The gel time and growth rate of the radius of gyration were also investigated. Understanding gelation processes can have applications in various technologies such as polymer network, biological systems and synthesis of aerogels and aerosol gels.

Basic principles of scale, fractals, fractal dimension, and light scattering were developed into hands on educational sessions for high school students as part of the GK-12 fellowship. For example, students at Junction City High School worked in groups to cut out tape paper to understand the nanoparticles size. Another class involved the concept of fractals and their dimensional properties which was introduced to the class for the first time. Projects prepared were used to decorate the classroom.

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Unsupported Palladium Nanoparticles for Ethanol Oxidation in Alkaline Fuel Cell*
The nanomaterials have more importance in the development of new catalysts for fuel cell applications. Recently, research has been in the synthesis of carbon-supported palladium nanostructures. The objective in this work was synthesized unsupported palladium nanoparticles by chemical reduction method using NaBH4 as reducing agent. These nanoparticles were studied for the ethanol electrooxidation in alkaline medium using cyclic voltammetry. The electrochemical measurement in presence and absence of ethanol solution were carried out using glassy carbon electrode modified with the palladium nanoparticles ink. The X-Ray Spectroscopy (XPS) spectrum confirms the formation of the metallic palladium nanoparticles. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) show an aggregation of the palladium nanoparticles after chemical reduction forming clusters and the particles size distribution was of approximately 10 nanometers. The electrochemical results demonstrate that the unsupported palladium nanoparticles have an excellent electrocatalytic activity for ethanol oxidation in alkaline medium with high stability. These results promise that the palladium nanoparticles are a material for ethanol sensor and fuel cells applications.

As a GK-12 fellow of the PR-GK-12 program "From Hectares to Nanometers: GK-12 Multidisciplinary Explorations of Tropical Ecosystems and Functional Nanoscience," I have to develop educational modules based on my research, thus bringing research into the classroom. To achieve this objective was created a module for upper undergraduate, graduate students and teachers in which participants design cost-effective fuel cells using the cyclic voltammetry techniques. The objective of the module was to introduce electrochemical basics concepts. The electrochemical techniques are used in nanotechnology and are challenging to understand it. This was implemented in the GK-12 monthly meetings in order to introduce nanotechnology techniques to environmental science students and teachers. Other concepts applied in this module were the superficial area, catalytic, fuel cells and ethanol oxidation.

In this activity, participants prepared a working electrode made of carbon paste. The idea was to compare the area of the electrode with other commercial electrodes such as Glassy Carbon (GC) and Palladium. Then, they had to modify the carbon paste electrode and GCE with palladium nanoparticles to compare the catalytic activity of an ethanol solution. Finally, they had to choose the best electrode to a fuel cell taking into consideration the cost, superficial area and catalytic activity for the ethanol oxidation.

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Articulating A Research Study Of Alzheimer's Disease In High School
Alzheimer's disease (AD) is a neurodegenerative disease known for memory loss. Another common form of it is dementia, which affects nearly 6 million Americans and is the one of the top ten leading cause of death in the United States. AD is an idiopathic disease, where the cause of it is not known and is being investigated. AD patients show high levels of abnormal peptides or proteins called Amyloidβ (Aβ). Aβ is neurotoxic and readily aggregated. It is hypothesized that Aβ peptide and its aggregation are causing the initiation of AD. Aggregation occurs when Aβ proteins collect and clinch one another to form structures called fibers that are present as plaques in the brain. When several Aβ align, they form a network of salt bridges and strong hydrogen bonds between ionized chains of opposite charge resulting in plaques. Different methods were developed to quantify the aggregation of peptides such as nucleation dependent polymerization, in which the process of aggregation is studied by analyzing the different steps of protein aggregation. There exist three steps, in which the aggregation can be studied qualitatively and quantitatively. In this study, a short key sequence of Aβ peptide that is crucial for its aggregation, was studied as a

model system to better understand the whole Aβ peptide and its aggregation process. During the process, a crucial residue was identified that slows down the aggregation of the key sequence and could result in therapeutic targets to help the fight against this disease.

This STEM Research was integrated in the classroom as an ongoing process. The students are first learning about the importance of developing models to understand complicated problems as I explained my approach to solve a complex human disease. The students were introduced to chromatography to understand how separation happens and to prepare them for later experiments such as the separation of amino acids. The amino acid chromatography allows the students to understand intricate concepts such as polarity and interaction relative to chemical structures. Amino acids can introduce the difference between acidic and basic residues relative to their structure. This can also be expanded when talking about ions and reactions to introduce salt bridges and different interactions that Aβ undergoes to form fibers. The STEM research not only allows students to explore a common disease but also to provide a connection while studying chemistry throughout the year

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A Mathematical "Cake Walk" from Chaotic to Periodic Burst Patterns of Neurons

Some neurons exhibit bursting oscillations in order to modulate certain brain functions within the nervous system. Mathematical models are often employed to simulate such behavior. In this investigation, both mathematical analysis and numerical calculations were used to study the transition of the dynamic behavior in a system of two neurons coupled via synapse, using the Hindmarsh-Rose (HR) neuron model. The individual HR neuron model depicts square-wave type bursting that displays chaotic behavior. Specifically this refers to unpredictable variations in spike number during the active phase of a neuronal burst. However the burst period can be regularized when the model is expanded via coupling with another neuron. A geometric analysis of the coupled neuron system shows that the transition from a chaotic to a regular, periodic pattern of neuronal firings is due to changes of the model's underlying mathematical structure.

As part of the NSF GK-12 MAVS Project, an important aspect of my research was grafted into Algebra I curriculum by involving students in the phase plane analysis of the underlying structure of a simpler, linear model. In one lesson, pipe cleaners were used to model parameter changes of linear functions and the subsequent effect on neuron spiking. In another, students constructed a "cake walk" to illustrate periodic solution trajectories. The cooperative learning format of the research lessons allowed for great student questions and discussions that centered on foundational ideas in my research.

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On the Reliability of RAID Systems

RAID storage systems are an IT industry standard in providing reliable, long-term storage of large quantities of digital data. In RAID systems, data is stored redundantly across a group of hard drives such that the failure of a few drives does not result in any data loss. However, in any RAID, data will be lost if too many drives fail simultaneously. In my research, I attempt to mathematically quantify the reliability of these systems under real world operating conditions leveraging the techniques of continuous time Markov chains. There are many parameters that affect the reliability of RAID systems such as the size of the system, degree of redundancy, reliability of individual components, and speed with which failed components are replaced. Our model considers all of these parameters as well as more nebulous factors that have not been included in previous studies of RAID reliability. For example, when a damaged RAID system is serviced, a mistake might be made that further damages the system. This possibility lowers the overall reliability of the system, but is not usually accounted for when designing RAID systems. We conclude that RAID systems are not as reliable as is commonly assumed. Additionally, we found that large RAID systems are more reliable than small RAID systems for a fixed redundancy rate.

In my GK-12 mathematics teaching at St. Gregory's College Preparatory School, my interests in mathematics, computing, and information theory have prompted conversations about the importance of mathematics in the technology in which students are immersed. We have discussed issues of data reliability and the mathematical techniques that provide reliability through redundancy, as well as the representation of data as binary strings. This semester, I am developing a computing module in which my students will learn to program in Python. We will focus on using computers to solve problems that otherwise are intractable and to automate calculations that are otherwise tedious. Through writing their own programs, I hope my students will gain a greater understanding of how their computers work 'under the hood' and the fundamental roll of mathematics in this technology.

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A Novel Approach to Gene Networks

Living systems are typically able to maintain their physiological state under environmental changes and isolated genetic mutations. This robustness, referred to as homeostasis or canalization, is achieved through feedback within highly connected regulatory networks of genes, proteins and metabolites.

There are hundreds of genes, proteins, and other molecular participants associated with most biological processes. Gene regulatory networks model all interactions between these nodes. However, the forms of these dependencies, as well as kinetic parameters such as reaction rates and diffusion constants are, at best, only known approximately.

We proposed a novel approach(1). Rather than attempting to derive an accurate model of the network, we asked what questions can be addressed using lower dimensional, highly simplified models. More importantly, is it possible to use such robust features in applications?

We first identified a small group of genes that can be used to affect changes in other nodes of the network. The reduced effective empirical subnetwork (EES) can be computed using steady state measurements on a small number of genetically perturbed systems using DNA microarray experiments.

We showed that the EES can be used to make predictions on expression profiles of other mutants, and to compute how to implement pre-specified changes in the steady state of the underlying biological process. These assertions are verified in a synthetic influence network. We also used previously published experimental data to compute the EES associated with an oxygen deprivation network of E.coli, and use it to predict gene expression levels on a double mutant. The predictions are significantly different from the experimental results for less than 30% of genes.

Our proposed approach to model gene networks uses ideas from complex system analysis and nonlinear physics. Although these topics are usually not covered in GK-12 education, teachers and students can be introduced to it through science projects and lessons or activities.

Using their own social network data from facebook, students were introduced to the field of network science. Students collect, analyze and visualize their social network. Definitions and properties of networks were discussed. For these activities scripts were developed that automate the parsing of facebook data. The project is still under development and lesson plans will be submitted to teachengineering.org.

(1) Gunaratne GH, Gunaratne PH, Seemann L, Török A (2010) Using Effective Subnetworks to Predict Selected Properties of Gene Networks. PLoS ONE 5(10): e13080.

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Connecting Topics of Physical Science to Observations of Potentially-Hazardous Asteroids

Through studying asteroids, we take a look at Near-Earth Objects (NEO) for potential threats, possible sources of minerals or other resources, evidence of life outside of earth, and spacecraft targets for further research. In June 2011 and November 2011, two asteroids (2011 MD and 2005 YU55, respectively) passed by Earth at extremely close distances. As part of the NEO observing team led by Dr. Michael Hicks from JPL/Caltech (Jet Propulsion Laboratory) at Table Mountain Observatory I assisted in the data collection using photometry. The objective for studying these asteroids is to determine their geometries. Using lightcurves, we are able to determine their rotational period as well as their classification. Participating in these observations has provided me with a more in-depth understanding of the process used to create the the Sloan Digital Sky Survey. The main focus of my research is to perform data analysis of a large survey that scans the sky and records orbital elements, colors, and magnitude. The data analysis uses IDL to plot 2100 objects to compare slopes with taxonomy, which yielded unexpected trends between the different types.

The IMPACT LA (Improving Minority Partnerships and Access through CISE-related Teaching) program at California State University, Los Angeles has provided the opportunity to bring research about close encounters with asteroids into the 8th grade physical science classroom at Stevenson Middle School in East Los Angeles, so students are able to see images of data and animations of the compilation of these images. The activities that were brought into the classroom explain how telescopes track objects and how scientists can use empirical data to draw conclusions of composition and features of an asteroid.

The first activity involved using an air cannon, which produced smoke rings, for students to measure how fast the smoke ring moved by recording the change in position over time. From this activity the students can understand how telescopes can track asteroids by computing their velocity. Through determining the density or composition of an asteroid, scientists can extrapolate other factors

about the object such as size, shape, and rotational period. The second activity incorporated engineering as the students used different materials to make an object float. This related very well to understanding the composition of asteroids through lightcurve data. Lightcurves allow comparisons to other asteroids with a similar type.

Mathematics and Physical Science / Engineering

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Protein Nanowires: From the Laboratory to the Classroom

My dissertation work concerns the creation of protein-based materials which possess electronic properties. These nature-inspired materials offer a level of structure and specificity unique to biological systems: the ability to create nano-structured materials under ambient conditions through natural precursors. This project studies two types of protein nanowires through the templation of (1) energy-transferring gold nanocrystals and (2) magnetic ferric oxide nanocrystals on alpha-helical cartilage oligomeric matrix protein coiled coil (COMPccs) variants. The aim of the research is to be able to predict electronic properties of protein nanowires by defined chemical changes to the protein structure. The templation of metal nanoparticles on protein fibers imparts upon them electronic properties, for potential implementation as alternative materials for energy harvesting or storage.

As a GK-12 Fellow, I use the topic of my research to capture the interest of middle school children in STEM subjects by exposing them to the field of novel biomaterials. Through experimentation using robotics, sensors, and materials analogous to the tools I uses in my biotechnology lab, I engage, mentor, and challenge students both in the classroom setting and in coaching a robotics team in preparation for a city-wide competition. Working with me and a partner teacher, the robotics team was able to develop, apply, and enhance their STEM skills though participation in a robot challenge and a research project in which they studied bacterial growth from food sources. My robotics team visited my research laboratory, with the unique chance to see the equipment I use daily to make protein materials, thereby promoting active learning through discovery and example.

In an additional outreach initiative, in October of 2011, I entered and won an essay competition with Time Warner Cable's Connect a Million Minds, describing how I connect children to science. The result was a $5,000 grant for NYU-Poly's GK-12 project as well as my being featured in a public service announcement where I talk about my role in and the importance of STEM education. The PSA is on the Connect a Million Minds website and is being run on 60+ local television channels.

Social, Behavioral and Economic Sciences

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Learning the Intersection of Environment and Energy

Community forestry in Nepal seeks to devolve forest governance to forest dependent communities with varying degrees of success. Biogas is a renewable energy technology, and Clean Development Mechanism (CDM), designed to replace other cooking fuels, primarily firewood. In Nepal, biogas is created from cattle manure and human sewage, thus also serving as a sanitation method. By reducing firewood dependence, biogas improves human health, conserves forest resources, and reduces carbon dioxide emissions making it eligible for carbon trading credits. This study results from 17 months of fieldwork with nine community forest groups in Jhapa and Gorkha districts. Analysis is based upon over 300 stakeholder interviews and primary documents collected from government sources, community forest groups, and businesses. My research analyzes the intersection of community forestry and biogas in Nepal by exploring environmental governance in relation to community forestry, biogas, and carbon trading, and how individual household energy decisions are embedded in global climate change and carbon trading agendas.

As a NSF GK-12 CarbonEARTH Fellow this year, I have been teaching 6th grade science. My goal is to translate my research into a basic understanding that our choices impact the environment and that environment and energy are connected. I am incorporating my research into the classroom in three ways: 1. Lessons and activities on forest habitat and forest dependent species, 2. A unit on water systems and sanitation, and 3. Lessons and activities on energy, including renewable energies and biogas.

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Smart Decline, Sustainable Society

Detroit, Michigan is losing housing and population at unprecedented rates without a realistic end to the downward momentum. The shrinking city phenomenon, as it is known in Europe and the US, encapsulates many of Detroit's problems. One of the issues is the haphazard withdrawal from Detroit's neighborhoods, creating large areas of weak, low population density interspersed with healthier, high density areas. As a result, Mayor Bing and city planners are looking for ways to stabilize its neighborhoods.

Smart Decline, a popular urban planning method addressing shrinking cities issues, argues for the consolidation of weaker neighborhoods into healthier ones. Using proportional hazard models, probit analysis, and spatial autoregressive models, my research will involve the testing of various urban decline models to determine which model or models are best able to identify neighborhoods that have the highest probability of decline and also stability. Identification of key explanatory variables for their future policy implications will also be important.

Studying shrinking cities is challenging because it ultimately involves humans and choice: the choices of those in positions of government, business leadership, city residents and others. In bringing this topic into the classroom, the need for sustainability is discussed, along with the need for a regional land use management approach and compact city planning models. The city of Detroit is losing population and abandoned homes are being torn down, but on the urban/suburban fringe, urban sprawl is converting farms and woodlands to large, low density subdivisions. Understanding the human inhibitors for doing what is right for the environment, city's residents and the city's future, and the role of government in bringing it all together, is key. High density compact cities are argued to be ideal because of their efficiency and their many environmental and social benefits, but the cost in building these cities is prohibitive.