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Biology

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Insights into Plant Fat: Integrating Plant Biochemistry & Sustainable Technologies

Concepts from biology and chemistry are being used to understand an essential process that all plants perform: the production of lipids (fat), specifically surface/cuticular wax. Cuticular wax is the shiny, wax substance that accumulates on the outer portions of the plant (e.g., leaves). Although some plants produce more wax than others and the composition of cuticular wax can vary among plants, we do know that there are several different constituents that must come together to form an intact wax layer. How some of these molecules are produced is known, but the overall pathway/process of production is not well understood. We have elected to use modern corn, Zea mays, as a model system to study the pathway for cuticular wax production. Within corn, there are ~30 glossy mutants that are identified because their surface wax is modified or lacking. The name stems from the dull appearance of normal leaves versus the glossy vibrant appearance of mutant leaves. To understand the function of each glossy gene within the pathway, the glossy mutants were grown and the specific constituents within the plant's wax were compared to non-mutant plants. Understanding this pathway is a useful tool not only for the fundamental knowledge that it provides, but also for the production of biofuels as many of the constituents that make up cuticular wax are potential candidates for next generation fuels.

Integrating this research into the middle school classroom has developed into a mini-unit focused on corn and its downstream uses in society. The mini-unit provides a hands-on experience for the students to see an agricultural process occur beginning with a cornfield and ending with each of them, the consumers. First, teosinte, the progenitor to modern corn, and its evolution into modern corn were researched and discussed, highlighting the importance of genetic selection and its importance to human society. We then examined ears of field corn and the students harvested their own kernels, which were used in our classroom research project, titled: Which plant is lacking its proper rain coat? Students identify which plant is a glossy mutant and has an abnormal waxy layer on its leaves. If the plant has an intact wax layer when water is sprayed on the plant the water rolls off, conversely on mutated plants the water beads up. To identify this phenotype, students spray water on 14-day-old seedlings and observe water beading. After germination of the kernels, students dissect the kernels and identify the four major parts, observing differences in appearance and learning the usefulness of each part to plants and people. Emphasis was put on what gives rise to the cooking oil we purchase from the store and consume as food. From this point each student made biodiesel from store-bought corn oil. The home-made biodiesel was then burned, demonstrating to the students that it is a real product that can be used in diesel engines. Upon separating the biodiesel from the waste product (glycerin), the students used the waste glycerin to make soap they could take home and use with their families. The mini-unit provides the students with multiple examples of the roles fat plays for both humans and plants.

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Project Flowing Waters: An Outdoor Learning Experience

The use of outdoor learning spaces is important for enhancing student interest in science. In Project Flowing Waters, we capitalize on the richness of local aquatic environments to make biology and earth sciences attractive and exciting to middle school students. The project is a collaboration between Texas State University-San Marcos and the San Marcos CISD (SMCISD) in which doctoral students from the departments of Biology and Geography collaborate with local science teachers to develop inquiry-based science lessons based on the 5 E Learning Cycle Model. Science lessons are designed to support the science content standards for Texas (TEKS) and help students achieve understanding by building upon natural curiosity to investigate questions using the natural environment as a science laboratory. This is especially important to the current generation of predominantly urban students who have little experience with the great outdoors. In one example, fellows and teachers take students to a nearby pond to describe the biotic and abiotic habitats in order to investigate interactions between organisms and their environment, and the impact of human actions on freshwater habitats. In turn, outdoor resources can also be brought back into the classroom to investigate complex principles, such as Newton's laws, the heating and cooling of earth materials and plant water uptake. We develop activities that encourage students to explore the broader implications of what they learn and apply it to their current framework of knowledge. We describe some of these activities, students' reflections, and future plans for using the outdoors to enhance the students' learning experiences.

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Incorporating Biofuel Research into STEM Education

Lignocellulosic ethanol produced from inedible plant material can reduce our dependence on fossil fuels, but current biochemical biofuel platforms are not viable due to hydrolytic enzyme costs. To address this challenge we have optimized operational parameters for a novel two-stage bioreactor. In the first "nursery" reactor, fungi encapsulated in porous gel beads excrete a suite of lignocellulose degrading enzymes. Enzymes are easily separated from the encapsulated fungi and used to convert bio-mass to sugar in the second “hydrolysis” reactor. These sugars can be fermented to ethanol. Flasks containing purified cellulose (Avicel) were inoculated with encapsulated or unencapsulated Trichoderma reesei and monitored for enzyme production. The encapsulation matrix composition and reactor characteristics were varied to optimize enzyme production and recovery. Enzymes from the nursery were used to optimize a hydrolysis reactor containing Avicel or sawdust. Hydrolysis reactor products (i.e. sugars) were tested as enzyme inducers for continual operation of the nursery reactor. Enzyme activity of encapsulated T. reesei was initially 13% less than the unencapsulated treatments. However, successive nursery reactor runs produced increasingly higher levels of enzyme activity over three weeks. Subsequent hydrolysis activity of the encapsulated enzyme solution was 14% - 40% higher than their unencapsulated counterparts. Feeding hydrolysis reactor products to the nursery reactor yielded enzyme activity comparable to that of Avicel. We have optimized conditions for a bench scale lignocellulose hydrolysis reactor. These data are being used to parameterize a pilot-scale reactor. Utilizing on-site enzyme production and hydrolysis products to maintain the nursery reactor should lower biofuel production costs.

This research has led to classroom activities that teach biological concepts while solving engineering problems in a biotechnology framework. Students create bio-ethanol using different carbon sources and devise strategies for quantifying ethanol production in bioreactors they have designed. The concepts of direct and indirect measurements are explored. Through experimentation students discover the biological and industrial importance of enzymes. Lastly, the class uses current methods to isolate cellulose degrading microbes from local waterways and soil. These isolates are analyzed for enzymatic activity and compared to the activity of industrially important microbes.

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Susceptibility of the Vascularization in the Paraventricular Nucleus of the Hypothalamus to Altered GABAB Receptor Signaling, Endogenous Sex Hormones, and Prenatal Stress

The paraventricular nucleus (PVN) of the hypothalamus plays important roles in regulating sympathetic vasomotor tone, food intake, stress responses and cardiovascular function. The PVN also contains a denser matrix of blood vessels than the surrounding brain regions that develops postnatally in rats and mice. A series of studies are being conducted to determine factors that are important for the development of this unique vascularization. Endothelial cells that line blood vessels were visualized by immunohistochemistry to examine vascular density. The PVN contain GABAB receptors that play a role in development during fetal life and mice lacking the R1 subunit of the GABAB receptor were examined to see if this influence extends to the postnatal vascularization. Vascular branching was taken as an index of vascular density in a region of interest inside the PVN. Results showed GABAB receptor knockout mice had a significant decrease in vascular branching than wild type control mice. In addition, the synthetic glucocorticoid dexamethasone has been shown to increase the number of endothelial cells *in vitro*, which suggests the potential to increase angiogenesis *in vivo*. Dexamethasone is administered prenatally for proper lung development in humans, but the extent this plays on the developing vascularization in brain is unknown. To begin testing this role in a preliminary experiment, dexamethasone was injected into pregnant mice during the last half of gestation. Results will determine if excess levels of glucocorticoid stimulation, alone or in combination with the lack of endogenous sex steroids during postnatal development, will alter the vascularization in the PVN. Changes in vascular branching may alter the ability of the PVN to properly receive signals and respond appropriately.

These findings were integrated into a general biology high school classroom through examples and demonstrations. Students had direct contact with brain tissue and shown how they were collected. Next, students viewed slides produced through immunohistochemistry of these brains and were able to view the vascularization in the PVN. This exposed the students to how researchers go about testing hypotheses. In addition, this experience showed them that many factors combine to impact the development of an organism.

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Breeding Systems of *Guaiacum sanctum* (Zygophyllaceae)

Plant breeding systems and the factors that regulate sexual systems in natural plat population may influence frequency and quality of reproductive events. Information on breeding

systems are very important to establish effective management and recovery programs for rare and engendered plant species. *Guaiacum sanctum* is a slow growing small tree species in the Zygophyllaceae and is an important threatened timber native tree species from neotropical dry forest life zone and listed in Appendix II of CITES. The lack of information on the reproductive ecology of this species limits our ability to design and improve conservation and management plans for this species. We combined data on fruit and seed production from natural pollinated and experimental hand-pollinated flowers to determine the breeding system of *Guaiacum sanctum*. We selected 10 individual trees on Mona Island reserve and applied five different treatments with five replicate flowers on each. Pollination treatments differed in the number of fruits produced. Artificial cross-pollinations produced twice the fruits and twice the seeds produced by the artificial self-pollination treatment. The bagged pollination treatment produced almost no fruits or seeds relative to the open (control) pollination treatment. Suggesting that *G.sanctum* requires animal visitations for pollination to take place and that this species is not autogamous. The apomixis treatment produced no fruit in dicating that no seeds are produced from unfertilized ovules in *G.sanctum*. Percentage-wise, open natural pollinations produced slightly less fruits than artificial cross-pollinations but these treatments were equivalent in terms of seeds set. The combined results may suggest that pollination may be some what pollination limited (fruit set differences), but that natural pollinations are likely to be generated predominantly by outcrossing (equivalent fruit sets between open and outcross-pollinations). The value of the ISI index was 0.63, Indicating that *G. sanctum* have a partial self-incompatible breeding system.

This research projects was introduced in the classroom as an introductory scientific talk. In addition, a problem-based learning activity which included role play was designed to introduce the students to the problems and challenges in the field of plant conservation biology.

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Integration of Remote Sensing and Statistical Modeling Techniques into the High School Classroom

My research focuses on modeling the effects of physical components of the environment on the early life history of yellow perch in the western basin of Lake Erie. In particular, I am interested in the effects of different types of turbidity, sediment and phytoplankton, on the growth and abundance of larval and juvenile fish. I use remote sensing, in the form of satellite imagery and water quality monitoring, along with statistical modeling techniques, such as Soil and Water Assessment Tools (SWAT) and Individual Based Modeling (IBM) to link changes in the watershed to alterations to the yellow perch population. Results, so far, have shown that turbidity levels and type alter the growth and abundance by altering the ability to feed, as well as changing the predation risk, resulting in areas with high growth potential, but also high mortality risk. This may alter the recruitment of juveniles into the fishery by altering the size distributions of a cohort.

I integrate my research into the class room in a number of different ways. The program I assist with is focused on environmental issues, and in particular, water quality. Students use freely available satellite imagery (MODIS, LANDSAT) and precipitation/ water level data (NOAA, Heidelberg University) to link storm events in the Maumee River watershed to the large sediment plumes visible on the satellite imagery in the following days. This allows students to make a connection between land based processes, such as erosion and sewer overflow, to changes in the lake environment. Basic mapping and modeling techniques are also employed, by having students map their water sampling sites on basic GIS maps, and developing simple statistical models of stream flow and pollutant levels. Much of this is done through hands-on learning, using the respective computer programs, image servers, and in the field water testing. There is some standard lecture format to explain concepts, and allow students to become familiar with the terminology used in remote sensing and modeling.

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Middle School Students Conduct Conservation Research by Tracking Toads

Sixth, seventh, and eighth-grade students from Walter Strom Middle School in Cle Elum, Washington have become an integral part of a Master's of Science project at Central Washington University (CWU) which examines the seasonal movement patterns of Western Toads (*Anaxyrus boreas*) adjacent to Interstate 90 (I-90). Middle-school students who participate in a "watershed club" as part of CWU's NSF GK-12 Yakima WATERS program have the opportunity to conduct fieldwork as part of an extensive multi-agency project. Currently, Washington's Department of Transportation (WSDOT) is working on an expansion project to widen I-90 in the Snoqualmie Pass area and will be incorporating animal crossings above and below the road surface. This expansion project is the first in the nation to consider all vertebrate species, instead of just mammalian species, whose movement may have been affected by a highway. Western Toads are good candidates for amphibian movement studies because they are known to migrate between breeding sites, summer foraging ranges, and overwintering sites, and travel long distances relative to their size. Twenty-five toads have been radio tracked since July of 2009 to the present date. Toads were outfitted with radio transmitters (BD-2, Holohil Inc.) mounted on waist-belts made of polyethylene tubing. Each toad was tracked 2-3 times per week using a Telonics TR-4 receiver with a Telonics RA-17 directional antenna. Upon locating each toad, GPS location and habitat data were collected. Preliminary data (n = 25 toads) have shown that they have a great capacity for movement (>2km over a 2-day

period) and use a wide variety of habitats. Approximately once a month, middle school students who are active participants in the watershed club are selected to radio track Western Toads.

These data will be incorporated into a Master's of Science thesis project at CWU and provided to WSDOT to enhance local toad habitats and identify sites for appropriate crossing structures. By identifying key areas of use by Western Toads, conservation and management decisions will be able to reduce the impacts of I-90 on amphibians by improving habitat connectivity. In addition to collecting data, students have been filmed and interviewed while conducting fieldwork. A short documentary is being assembled that will be used to educate community members about the importance of wildlife conservation and demonstrate Walter Strom Middle School's connection with local environmental issues.

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Selective Isolation and Characterization of Mature miRNA

MicroRNAs are a class of recently discovered small RNAs that are found in both plants and animals. Unlike messenger RNA, microRNAs are not translated into proteins[1]. It has been established that microRNAs control numerous plant developmental processes such as leaf, flower, shoot, vascular and root development[2]. Recently it has been demonstrated that microRNAs are involved in fighting plant diseases caused by different pathogens. MicroRNAs have therefore gained a great deal of attention from scientists especially given that pathogenic infections extensively affect plant growth and account for nearly 30% yield loss for most crops and fruits[3]. The goal of our research is to develop a novel assay for measuring mature microRNA. The assay combines use of a capture probe with an additional selection process to restrict measurements only to specified miRNA. We use the state of the art mass spectrometry to directly measure the microRNA. The results so far obtained reveal that our assay is highly selective and can discriminate against different types of microRNA present in the same solution. Recently, microRNA have been shown to be key players in plant nutrient acquisition, assimilation and metabolism[4].

To investigate the possible roles of various plant nutrients in both seedlings and mature plants, two different experiments were designed (a) beans grown in different soils and (b) hydroponically grown oats. For experiment (a), student teams grew medium white beans in sand, clay or humus. Germination time and growth were recorded by counting the number of leaves and measuring the height of beans. The beans were later uprooted and the root system studied. Results: Plants grown in sand showed underdeveloped root system and signs of leaf blotching as well as discoloration which indicated lack of phosphorus. In the clay soil, plant growth was considerably slow and plant leaves turned yellow; a sign of nitrogen deficiency. Normal growth was observed for plants grown in humus. For experiment (b), oats seedlings were hydroponically grown using three different nutrient solutions containing varying amounts of phosphorus, nitrogen and potassium. The setup allowed students a means to study the need of specific nutrient. Data on height and physical appearance were collected and graphed in order to determine the most effective fertilizer. Conclusions about the deficiency of certain minerals could therefore be drawn.

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Computer, Information Science and Engineering

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DNA Rockstar: Presenting Educational Content Within Interactive Media

Children are immersed in an ever-increasing world of interactive media. Their social interactions are mediated through video games, social networking web sites, and cell phone communication mediums. This media is rich in content, as well as visual and auditory stimuli. The experience in the classroom however, has not kept up with this media trend. Pencil, paper, books, and blackboard are still the dominant media in most schools. We created "DNA Rockstar" as an attempt to introduce an interactive multimedia experience to teach concepts such as genetic translation and protein synthesis. By treating each nucleotide base as a note in a song, students learn that a small set of basic building blocks are arranged in varying patterns to create all life on Earth (just as a small set of notes creates all songs). The current version is a simple reaction-time game, such that learning content and user behavior are not well integrated, but later versions will develop a much richer learning experience. As a social scientist, I am also interested in examining how issues that might generate more interest for under-represented students—the genetics of race, sickle cell anemia, DNA ancestry tracing, etc.—could be integrated into the learning content.

Engineering

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Control Algorithms for Mirror Shaping and Precision Pointing of a Segmented Telescope

With the increasing desire to see further into space comes the need to improve the current space telescope technology. To do so, it is necessary to increase the area of a space telescope's primary mirror. The difficulty in manufacturing a single paraboloid mirror increases as size increases. In addition, the size of these mirrors is restricted by current space launch vehicles. NASA's next generation space telescopes, such as the James Webb Space Telescope (JWST), will use a segmented primary mirror as a solution to overcome these difficulties. Mirrors used in space telescopes require a high level of precision to obtain clear images. The segmentation of the primary mirror leads to complexities. Each of the mirror's segments must maintain near perfect alignment. Any disturbances will result in blurry images. In addition, the telescope must maintain its pointing accuracy to the object in question. This research focuses on developing control algorithms to maintain the shape of a segmented mirror as well as increase the pointing accuracy of a large scale space telescope in the presence of noise and disturbances.

In bringing this research into high school math classrooms, students are first introduced to activities involving general space exploration. As the year progresses, topics in Algebra 1, Algebra 2, and Geometry are paired with concepts related to the segmented telescope control research. One Geometry activity involves scaling of images and 3D objects. Students draw scaled versions of 2D images using a grid, as well as, build 3D objects to scale. Engineers must build scaled down versions of complex systems in order to test their designs, such as the telescope testbed in the CSULA NASA SPACE Lab, a scale version of the JWST on which control algorithms are tested. Another activity involves having the students explore properties of reflections off of a mirrored surface by pointing a laser at different angles to the mirror and measuring the three angles formed. On the JWST testbed, a laser system that simulates the light from a distant object is being developed to test the pointing accuracy of the telescope. Properties of reflections are used in developing these simulations. A third activity has been developed for Algebra 2. Students calibrate a small projectile launcher in order to hit a target with as much precision and accuracy as possible. Students must determine the initial velocity of their launcher at specific launch angles. On the JWST is necessary to maintain the calibration of sensors and actuators involved in mirror shape. Without proper calibration of equipment, a large scale, complex system such as a space telescope will not operate as desired. These are only a few examples of activities that allow students to see how math is used in engineering and space exploration.

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Dual-Gelling *In Situ* Polymer Systems for Aneurysm Treatment

Cerebral aneurysms, bulges formed in blood vessels, affect approximately 10-15 million Americans and can result in hemorrhage, stroke and potential fatality. Current treatments are highly invasive or can cause re-bleeding. We are investigating use of an *in situ* gelling polymer system to improve current treament methods. The polymer gel would essentially be injected in the aneurysm sac, solidifying and preventing blood from entering. The polymer system consists of a simultaneous physical and chemical gel, through temperature-sensitivity and chemical reaction. Will the combined physical and chemical gelation allow for a better gel with optimal properties in the blood vessel? Will the tissues and cells respond well to the gels? The polymers were synthesized and characterized for their structural, chemical, thermal, mechanical, swelling and degradation properties. The data obtained demonstrates the successful synthesis of the copolymers (NMR and FTIR). Additionally, the copolymers were found (through differential scanning calorimetry) to have phase transitions ranging from 29 to 34°, ideal for injection in the body (at 37°C). Using rheology, the mechanical properties showed optimal results for the combined gelation system. Swelling studies have demonstrated the temperature-dependence of gel swelling. Under SEM, the gels were observed to have various pore sizes and morphologies. When tested on cells for cytotoxicity, the gels have shown good biocompatibility. These results are very promising and illustrate the potential for these gels to be used for treatment of cerebral aneurysms.

With the help of my partner teacher (Alysa Buxton, 8th grade science at SanTan Junior High, Chandler, AZ), I have used my research to design a 2-day lesson for her class involving learning about physical and chemical changes of properties, and designing gels for medical treatments. Through the lesson, students ultimately learned about the characteristics of physical and chemical changes, and investigated them using thermosensitive polymers and by mixing two polymer solutions, using samples I had prepared and brought. The students also tested different variables that affected these changes and identified physical and chemical changes which occur around them. We discussed how similar gels can be used for medical applications. Students chose a medical application for which gels can be used as treatment and designed a gel for that purpose. Their gel designs were then presented on posters and discussed with the class. Throughout the lesson, student misconceptions linked to chemical reactions and states of matter were addressed and discussed as a group to insure students' understanding. Having them use hands-on activities, their imagination and knowledge allowed them to design gels to treat diseases/medical conditions which were very similar to what scientists and engineers are currently developing.

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Parameter Study and Finite Element Analysis of a Multi-Hazard Protective Jacket for Structural Members

As the importance of protective engineering and multi-hazard mitigation design has grown in recent years, the development of an effective structural protection system that aids in the preservation of life safety during blast events is an important topic of research in structural engineering. This protection is especially vital for blast and explosion mitigation, where a vehicle-borne bomb or an improvised explosive device can readily cause an under-designed structure with insufficient redundancy to undergo progressive collapse due to the removal of its first-floor columns. An especially pressing topic is the consideration of structures that require blast protection, but—due to time or budget constraints, lack of available space, unusual construction techniques or other externalities—cannot be sufficiently strengthened by traditional structural hardening techniques such as those described in the FEMA counterterrorism design primers. As an alternative, the author proposes the development of an ablative, sacrificial protective jacket, based on prior research on the use of water as hazard mitigation to protect weapon storage facilities from accidental munitions detonation. The proposed system consists of a relatively thick layer of water sandwiched between two thin layers of polyethylene film or a similar polymer membrane, with the entire assembly wrapped around or affixed to the vulnerable structural elements. The water layer is theorized to reduce the incident and reflected pressure of the blast wave through two principal modes of attenuation: the reduction of the blast wave's energy through harnessing the high enthalpy of fusion and specific heat of water (the "thermodynamic mode") and the transformation of the blast pressure into kinetic energy (the "kinetic mode").

As part of his involvement in the NSF Graduate STEM Fellows in K-12 Education program, the author draws from this research to introduce to high school chemistry students to the methods of scientific research and computational analysis. The district's existing, prescribed curriculum requirements are supplemented by cooperative, hands-on research activities and problem-based learning projects based partly on aspects of this research, including introductory discussions of atomic bonding, thermodynamics, organic chemistry and polymers, as well as more general projects which familiarize students with data collection and computational analysis. These projects are augmented with technology such as laboratory probeware (Vernier LabPro), computer simulations (Algodoo, Avogadro) and multimedia presentations.

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Wind Energy: Blowing Renewable Energy into Sixth Grade Science Classrooms

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. The first round of tests were conducted using microtabs, and the tabs were found to be able to mitigate gusts of wind up to ten miles per hour. Future tests will examine the ability of microjets to control loads under similar gust conditions.

The UC Davis RESOURCE GK-12 program is bringing current research on renewable energy into fifth and sixth grade classrooms in the Sacramento area. 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. After this framework is established, specific ideas related to wind energy and my current research will be presented to students in the same hands-on, interactive style.

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Altered Micro-Environmental Conditions Lead to Congenital Defects

Currently, 1% of all Americans live with a congenital heart defect and 20-30% of these are valve related. The embryonic valvular malformations are among the more serious of heart defects due to the implications extending into the adult life. Valve formation occurs through a complex process of morphogenesis events which include extension along the myocardial substrate, condensation of the tissue into dense fibrous tissue, and delamination from the myocardial wall.

Previous literature has identified three growth factors (VEGF, BMP, and TGFB) which are present during this maturation process. However, the mechanisms by which these factors regulate this process are unknown. We hypothesize that direct control over the migration, compaction, and differentiation of embryonic valve cells (EVC) is possible by applying dose dependent profiles of these growth factors. To conduct these experiments, EVC were isolated from stage HH25 chick embryos and seeded onto 3-D collagen gels. A dose dependent response (0.1 - 100 ng/ ml) of each growth factor was evaluated. We report that TGFB3 enhances matrix compaction and migration with increasing dosage, but BMP2 had no effect on this process. Furthermore, TGFB3 administration upregulated key differentiation proteins suggesting a transition towards a mature valvular phenotype. Taken together, valve maturation is dependent upon TGFB3 and altered micro-environmental conditions affecting regulation of this protein could lead to congenital heart defects. How these basic research experiments translate to clinical relevance are often difficult to understand and interpret. This is due to the controlled environment which biologist and engineers construct to answer one specific question. When applied to larger systems, many variables are introduced and any global understanding of the mechanism may be lost.

Developing teaching curriculums follow a similar pattern such that the context of activities should inform teachers and teach students on many levels. Therefore, we implemented curriculum capable of addressing these needs through an ex-ovo chick culture system. This system allowed students the freedom to observe the development of chick embryos outside the shell and introduce micro-environmental conditions (variables) of their choosing. The specific goal of the curriculum was to (a) familiarize students with key features of morphogenesis such as limb, eye, and heart formation, (b) demonstrate the importance of a micro-environmental conditions by applying retinoic acid (vitamin A metabolite) to create a defect model, and (c) discuss the role of animal research in the study of congenital defects and disease. Throughout the process a detailed workbook was used to keep students on track and direct their thought process. In addition, the students were challenged to formulate hypothesis, determine variables, and quantify observations/results in the most informative way possible. What we hope each student will gain from this curriculum is (1) an appreciation for the complex micro-environment regulating embryonic development and (2) to recognize science as a dynamic and explorative process guided by scientific framework.

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Comparison of Novel CO2 Conversion Nanocatalysts

Metallic nanocatalysts supported by a high surface area activated carbon are being studied in a plug flow reactor under different conditions including catalyst loading capacities and temperatures to determine the optimum conditions for CO2 conversion to CO ($CO_2 = CO + 0.5O_2$). A mixture of CO2-N2 containing CO2 is used for tests and the concentrations of the gases prior to and after conversion process are measured using a gas chromatograph. The purpose of this study was to convert the increasingly concerned 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 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 CO2 - CO conversion nanotechnologies for clean energy production. They work with NSF Fellows to do on-site nanocatalysts 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 nanotechnology (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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Mental Schemas and Geometry: Measuring Geometric Shapes using Concept Maps

The overall research question is: Should mental schemas be considered to enhance usability for a more successful user outcome? Mental schemas are structures of existing information used by individuals to organize, interpret and make sense of new information and concept maps are visual representations or diagrams of concepts and their interrelationships, used to organize and represent knowledge for a topic or idea. My research aims to: 1) investigate the impact of the relationship between users' mental schemas and expert models of a system, which will be vital to making improvements to existing products or technology and accommodate different types of users; 2) examine the impact of schema structures of users based on varying levels of experience; and 3) determine the impact of training procedures on mental schema structures and will assist technology developers in designing appropriate training material and modules to make mental schemas more accurate for improved user performance.

This research could potentially help Engineering Education researchers in determining whether educational software improves student use or experience with technology. My classroom experiences and lesson plans have included applying cognitive theories to mathematical domains, specifically for the 10th and 11th grade geometry curriculum. One lesson plan demonstrated how to develop concept maps and use those concepts to construct a 3D model of a sphere, and calculate the surface area and volume using the appropriate equations. This lesson captured students' knowledge and understanding of three-dimensional properties of shapes and figures as well as shows them how their existing concepts can be applied to understanding and interpreting new knowledge. Students used the technique of concept mapping to help solve math problems using 3D spheres. Students were required to identify key definitions, measurements and terms associated with a sphere and draw a concept map showing relationships between their terms. Students were then asked to construct a 3D representation of a sphere using the supplies and material provided based on the terms generated in their concept maps and to apply equations for calculating surface area and volume of a sphere. Many of the developed GK-12 lesson plans have strived to demonstrate the interconnectedness between mathematics, cognition, technology and humans, in the hope that it will INSPIRE students to become engineers of tomorrow.

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Life Cycle Assessment of Using Rainwater for Toilet Flushing and Irrigating

With higher water demand and decreasing supply, harvested rainwater is becoming a popular alternative to using potable water throughout a building. However, the economic and environmental impacts of these systems, and the feasibility of applying these systems in both existing and new large scale buildings still remains to be explored. A typical dormitory at the University of Toledo was analyzed. Five scenarios were developed which allowed the comparison of using rainwater for flushing toilets and irrigating in an existing dormitory, a new dormitory and a dormitory with fewer occupants. The scenarios were compared using life cycle assessment and discounted payback period methods and with respect to their return on investment, their energy consumption and the global warming potential due to carbon emissions. Harvested rainwater can replace nearly 2 million liters of potable water annually at the analyzed dormitory. It was discovered that the energy payoff associated with using rainwater to flush toilets in an existing building may exceed the buildings lifetime. At the analyzed dormitory, the small roof area as compared to building occupancy resulted in an inadequate volume of harvested rainwater to supply the entire toilet flushing demand. With adjustments in current building codes with respect to roof area per occupant, payback periods may be reduced. The most sustainable end use at the dormitory was irrigating.

This research was integrated into the 10th grade honors biology course. I was able to obtain a rain barrel which will be installed at the high school. Several activities will be developed using the rain barrel to measure the volume of water collected and water quality. The runoff will be used to irrigate the school's rain garden and other areas. I have also introduced life cycle methodologies into the curriculum. Students are using Economic Input Output Life Cycle Assessment (EIO-LCA) to determine the energy consumption and emissions from several items including batteries, paper towels, hand dryers and recyclable containers.

Geology

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Detailed Sea Surface Temperature Record in the Southwest Pacific Ocean During the Last Time Earth Experienced Global Warming

The Pliocene Epoch (5.3-1.8 Ma) is the most recent geologic period of sustained global warmth. Understanding how the world responded to these warmer conditions has important implications as an analog for future anthropogenic warming of the Earth. Past climate reconstructions of the Pliocene warm period (pWP, 4-3 Ma) suggest that mean annual temperatures were approximately 3°C warmer than present, atmospheric carbon dioxide values were either the same or only up to ~25 ppm higher than current levels (~390ppm), sea level was up to 40 meters higher than today, and thermohaline circulation may have been stronger. These conditions make Pliocene climate reconstructions ideal for understanding how the world responds to warmer conditions. In particular, the Southern Ocean plays a key role in regulating global climate, so high-resolution reconstructions from this region are important to understanding global climate processes, including climate-ice-sea level interactions as significant amount of ice was only found in the southern hemisphere during the Pliocene. We present the first detailed record of surface conditions in the Southwest Pacific during the Pliocene warm period. We use temperature sensitive lipids (alkenones) made by organisms living in the surface of the ocean (coccolithophores) to infer sea surface temperatures (SSTs). We use the concentration of alkenones found to infer the productivity of the surface ocean. Production is the creation of new organic matter; in the ocean surface carbon dioxide is one of the primary contributors to creation of biomass; we also care about productivity because it allows us to trace ocean upwelling and infer shallow circulation. We find the average SSTs in the Southwest Pacific is 18°C, which is ~4°C higher than both modern annual median SST and glacial-interglacial changes in SSTs for the last million years. Alkenone concentrations exhibit high variability (up to 10 nmol/gram) with higher values occurring during glacial stages. The results suggest that the Southwest Pacific was warmer than previously thought and the variability of SSTs

from glacial to interglacial was greater. Productivity peaks during glacial times may have occurred due to more nutrient rich waters, a sign of more subantarctic-like waters in the area of study.

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Improving Food Security, Mitigating Climate Change and Generating Renewable Energy through Production and Utilization of Biochar

Global food security, sustainable development, climate change mitigation, and renewable energy have become major goals in the 21st century. The production of "biochar," a stable carbon-rich product of "pyrolysis," may offer a large lever for helping to solve many of these global issues. Biochar has been found to improve crop productivity in a wide range of conditions--particularly in degraded soils. Renewable energy can be generated during the pyrolytic process. Carbon can be sequestered for hundreds to thousands of years through biochar application. Thus biochar has been described as a win-win-win option for food security, climate change mitigation, and renewable energy production. Clean cookstove technologies capable of producing biochar were examined as a means of spurring sustainable development. Biogas technologies which produce methane (CH_4) from anaerobic digestion of organic materials have become widespread in India over the past several decades. The effluent generated from the process has been found to have beneficial impacts on crop productivity as most of the nutrients are conserved during the decomposition process. When combined with biochar, it may be possible to create a simple but effective sustainable fertilizer that can be produced from the byproducts of two different energy generation processes. Furthermore, utilization of anaerobic digesters in combination with pyrolysis units appear to dovetail tightly as evolved methane can be used to power initial stages of the pyrolytic process and waste heat from biochar production can be used to speed decomposition in digesters. Both technologies are of appropriate scale and expense for adoption in India and other developing countries. Biochar has been proposed as a novel means of sequestering carbon and improving plant productivity in highly degraded soils.

Significant time and energy has been devoted to integrating this research into K-12 classrooms. The 6th grade students at Greene Middle School in Mrs. Tamra Hershey's classroom were involved with and exposed to the research project from initial phases through development and beyond, and a 12-hour curriculum learning module has been developed for the class. Prior to leaving for research, two classes were dedicated to the discussion of poverty, food security, climate change, and renewable energy. While the Principle Author was in the small village town of Lakkihalli, India establishing the project, students were kept abreast through photos and letters that were maintained on a blog designed for that purpose. Presently, Greene Middle School Students are getting ready for the "Clean Cookstove Technology" module which includes modeling clean cookstove technologies, a simple cost-benefit assessment, and two homework sets on the project. Student questionnaires have been developed to assess the perceptions of the coursework through a survey designed to collect relevant statistical information.

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Connecting Urban Youth to Atmospheric, Biological and Earth Science Phenomena

Natural and anthropogenic processes on Earth directly impact our external and internal biological environments. Teaching 6th grade students aspects of earth, atmospheric and biological sciences shows them that changes to the environment directly affect their daily lives. GK-12 fellows devised lessons on the Newark Public Schools curriculum topics of mixtures and solutions, microworlds and weather and water that relate to environmental interactions based upon their graduate research. Air pollution is known to exacerbate respiratory health conditions particularly in urban areas and poses a threat to public health. Meteorological factors are significant precursors to the production and concentration of air pollutants. New Jersey has a finite amount of clean water and as population increases it is increasingly important to protect this resource. By understanding flow of runoff and groundwater through fractures and slope gradients, students can help protect the source of water they use. Manganese minerals are being investigated for their potential role in the remediation of toxins in soils and water. Exposure to contaminated air water and soil can lead to diseases such as cancer. Adherens junctions are important for development and wound healing as well as our understanding of metastasis during cancer progression.

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Exploring Changes in Local Watersheds Through Geologic Time

The Snake River basin drains 282,000 kms of the northwestern U.S. and is the largest tributary to the Columbia River. Redbird Beach, an archaeological site located in the lower Hells Canyon reach of the Snake River, contains extensive vertical exposures of archaeological materials interbedded with Snake River flood sediments. Redbird Beach formed in the lee of the Redbird Creek debris fan, and is composed of interfingering deposits from large floods on the Snake River and locally-derived alluvial sediments from Redbird Creek. Through stratigraphic analyses of prehistoric flood deposits, this study compares the temporal and spatial patterns of human occupation at Redbird Beach with variations in the magnitude and frequency of floods from the Snake River. As many as 30 Snake River flood

events formed the oldest portion of the Redbird Beach terrace at the downstream end of the site. Periods of historic and prehistoric occupation extending back at least 2500 years have been identified between flood events and correlate laterally within the flood stratigraphy. The oldest evidence for human occupation overlies pre-terrace forming paleotopography, and may represent a depositional environment much like the modern analogue at the upstream end of the terrace. Radiocarbon dates from detrital fragments and shells collected from organic material will constrain the ages of specific flood events and to determine the flood frequency. The prehistoric flood chronology of this reach of the Snake River, flowing between Washington and Idaho, has not been previously studied. Results of this study will form a key component of a regional synthesis of floods and climate change in the inland Northwestern U.S. and will contribute to our understanding of the archaeological record along this major regional waterway.

The Yakima Watershed Activities To Enhance Research in Schools (WATERS) is a National Science Foundation funded project at Central Washington University. As a graduate fellow, the WATERS project has given me the opportunity to incorporate my Master's research experience into local watershed science. In a general sense, my thesis research focuses on the relationship between geologic processes and human occupations. Similarly, in my 7th, 8th and 9th grade classrooms, I have integrated lessons that explore the relationship between the local landscape and human populations along the local Yakima River watershed, a tributary to the Columbia River that drains from the Cascade Mountains through Central Washington. The integration of local watershed science in the classroom provides examples that students can relate to, for example, testing local water sources and researching potential human causes of contamination, an authentic research project that the 9th grade students will present to their community in May, 2011. The WATERS program has enabled me to more effectively communicate my research and encourage students to appreciate science by looking out their back doors.

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A Solid Earth Educational Module, Co-operatively Developed by Scientists and High School Teachers through the Scripps Classroom Connection GK-12 Program

The Scripps Classroom Connection pairs local high school teachers with Scripps Institution of Oceanography (SIO) graduate students in the earth and ocean sciences for their mutual professional development. An integral goal of the program is the collaborative production of quality earth science educational modules that are tested in the classroom and subsequently made freely available online for use by other educators. We present a brief overview of the program structure in place to support this goal and illustrate a module that we have developed on the Solid Earth & Plate Tectonics for a 9th grade Earth Science classroom. This unit is related to the fellow's interest in geomagnetism and the ancient magnetic field: geomagnetism is an avenue to talk about the Earth's core and is a resource for understanding key evidence for plate tectonics. The unit includes 1) an exercise in constructing a geomagnetic polarity timescale which exposes students to authentic scientific data; 2) activities, labs, lectures and worksheets that support the scientific content; and 3) use of online resources such as Google Earth and interactive animations that help students better understand the concepts. The educational unit was implemented in two separate local area high schools for Fall 2010. The co-operative efforts of teachers and scientists lead to educational materials which expose students to the scientific process and current science research, while teaching basic concepts using an engaging inquiry-based approach. In turn, graduate students involved gain experience communicating their science to non-science audiences.

Mathematics and Physical Science

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Beyond the Text: Educating Students About Real-World Applications of Chemistry

High School science courses place very limited emphasis on light chemistry (photochemistry). Educating K-12 students about the use of light energy is advantageous because of the considerable scientific research ranging from therapeutic uses of light energy for targeted destruction of cancerous cells to the trapping of sun energy as a source of renewable energy. My research focuses on studying the mechanism of decomposition of potential light-activated anti-cancer prodrugs, tetrazolethiones. While these compounds have found widespread use in industries, there is still limited understanding about their mode of decomposition. Also, it is critical to account for all photoinduced product(s) within the chemical reactions if tetrazolethiones would be a suitable prodrug. The experiments to determine the mode of decomposition for tetrazolethiones were carried out in a Rayonet photochemical reactor and the results were analyzed using UV spectrometry, Nuclear Magnetic Resonance (NMR) and Laser Flash Photolysis, which helped to determine the mode of decomposition for tetrazolethiones. Thus far, our studies have revealed the vital intermediates as well as accounted for most of the products produced.

In order to enrich a high school chemistry course, an activity incorporating a portion of this research was designed. A field trip to chemistry department at Kansas State University provided the opportunity for the students to work with Rayonet photochemical reactor, where they were able to generate different photo-products and using NMR as a tool they were able to analyze their sample and determine what

chemical compound was formed. Also, the students carried out thin-layer chromatography of analgesics and synthesis of fragrant esters, so as to learn important chromatographic technique widely used by organic chemist as well as hands-on learning of types of reactions. Student knowledge of the above stated activities were evaluated using a pre-post assessment test. Future activities involve use of ultraviolet light to convert provitamin-D3, 7-dehydrocholesterol, to Vitamin D3, to mimic the formation of Vitamin D3 in the skin.

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New Results in Finite Geometries and How to Connect Them to K-12 Mathematics

In Finite Geometries, we apply techniques in Abstract Algebra and Geometry to a finite set of points satisfying a set of axioms. If we think of the set of real number and how it is used to coordinatize the Euclidean plane, we can in a similar fashion coordinatize an affine plane with elements of a finite field. By adding extra points to represent each possible slope, as well as including a special point representing the undefined slopes, we get a projective plane, which is a geometry without parallel lines. What if we wanted to coordinatize a plane differently? Would we get one of the planes coordinatized by the finite fields alone? The answer is no, in fact we could coordinatize the plane with a multitude of structures similar to fields including near fields and the structures that I work with called semifields. A semifield is a non-associative division ring. One of the easiest ways to obtain a semifield is by taking a field and changing the multiplication where the operation is no longer associative. In 1958 and again in 1961, Albert created such structures that he called “twisted fields” and “generalized twisted fields” respectively. In 1994 Cordero and Figueroa found an example that expanded on Albert’s work and we have now generalized this product to $x \cdot y = xy + Ax\alpha y\beta + Bx\beta y\alpha$. Our work is concerned with finding the general automorphism groups of the projective planes created from these semifields and finding which of these semifields differ from those of Albert’s work.

This year I have worked with Kimberly Helixon from Sam Houston High School in Arlington, Texas to connect my research to the curriculum in a double-blocked algebra/geometry course as part of my work as a NSF GK-12 Fellow at the University of Texas at Arlington. To achieve this, we designed lessons incorporating the topics of modular arithmetic, building projective planes using the concept of slope, adapting Kirkman’s schoolgirl problem and its relation to the projective plane, cryptography, and Latin squares. Similar lessons were developed last year for a seventh grade classroom.

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Cloud Optical Depth Retrieval Through the Use of Red and Near Infrared Light

Cloud optical depth is an important but poorly understood climate variable. It is the fraction of light power that is transmitted through a cloud. Fortunately, novel techniques have been developed to measure cloud optical depth. In the past, we have relied on averages over long periods of time to characterize this variable. These estimations were given to scientists because it is often used in the calibration of other atmospheric instruments such as a lidar (a laser range finder) which measures aerosol properties. Poor estimations of cloud optical depth ultimately limit the quality of atmospheric data. New techniques are being developed that will allow scientists to measure cloud optical depth more accurately and see the changes in the clouds as they occur. Red and near infrared lights transmit through clouds in a similar way, but reflect off the ground in different ways. Based on this concept, I am building an in-house radiometer that records the power of the light that falls at different wavelengths in the visible spectrum. Using this instrument, more data can be gathered to accurately reconstruct the cloud optical depth. Ultimately, this will allow for more accurate atmospheric measurements that will aide in our understanding of climate change.

Basic concepts of physics are taught at the middle school level. However, many middle school science teaches feel uneasy teaching the physical sciences. I was able to incorporate my research into the classroom using the learning cycle to teach students about light and wavelength. Fist, to engage students, the class watched a time-lapse video of clouds moving across the skies blocking the sunlight. I introduced the concept of my research on cloud optical depth by demonstrating to the class how I use the radiometer which measures how much light is transmitted through a cloud. To explore how clouds affect the amount of light coming through the atmosphere, students used a radiometer to measure the amount of light transmitted through different materials by a light bulb simulating the sun. After the classroom activity, student pairs were taken outside to use the radiometer in a real world application. Their ability to use the radiometer to measure the light coming through clouds demonstrated their understanding of the physical concepts of light and wavelength. To evaluate learning gains, student pairs presented their results to the class and then we discussed the connection between light, the atmosphere, and climate change. In the student-centered discussion, they were able to elaborate on the real world applications of my research.

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Bayesian Parameter Estimation for Gravitational Wave Sources in LIGO

The direct detection of the first gravitational wave will mark the beginning of a new era of astronomy. For the first time we will have the ability to observe the extragalactic universe through means other than electromagnetic radiation. Once opened, we must be prepared to make observations through this new window to the universe. There are many predicted sources of gravitational waves, one of which we believe can be modeled fairly accurately, namely the radiation emitted during the merger of two very compact objects (e.g. black holes, neutron stars). We present the use of Markov-Chain Monte Carlo methods, a class of Bayesian inference techniques, as a way to infer the properties of a compact binary system based on the gravitational radiation they emit. Students at Evanston Township High School, along with visiting Congresswoman Jan Schakowsky, were introduced to these techniques and the exciting future of astronomy. A demonstration of the Michelson interferometer, the detection technology used by LIGO to detect changes in distance on the order of 1000th the width of the nucleus of an atom, was used to aid the students in the understanding of waves and their interference.

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Studies on the Molecular Dynamics of Complex Systems

By studying the molecular dynamics of complex systems, one can learn the intricacies of the physics and chemistry, which occur at the solid/liquid interface of a wide range of materials. Implementing various techniques allows one to obtain valuable information on various phenomena, raging form protein folding to phase and glass transitions, that may lead to breakthroughs in condensed matter physics, materials science and technology. We present the results of our current research on the molecular dynamics of polymer nanocomposites and confined liquid crystals by various methods: Broadband Dielectric Spectroscopy (BDS), Differential Scanning Calorimetry (DSC), Dynamics Light Scattering (DLS), and Brillouin Light Scattering (BLS). We also present an educational module, as part of the GK-12 program, designed to bring the concepts that are implemented in our research laboratories to middle school children in the public school system.

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The Drug Discovery Process: From the Laboratory Bench to the Chemistry Classroom

The discovery of new medicines is a complex process. Before a drug candidate is tested in humans, scientists scrutinize it carefully to ensure that a medicine works the way it should. First, scientists must recognize a medical problem and identify a target within the body for that medical problem, which if hit, can lead to a cure. Next, scientists design and make molecules that can hit the biological target. Often times, scientists find inspiration for their designs from molecules that are found in nature. Small changes or additions to these molecules may cause a large increase in their effectiveness to hit the target. Each newly made molecule must then be tested against the biological target to make sure that the desired effect is produced. In our laboratory we carry out many steps of the drug discovery process. We study the Hepatitis C Virus (HCV), and have identified a specific section of its genetic code as a drug target. This section, which is known as the Internal Ribosomal Entry Site (IRES) contains a sharply bent structure which helps the virus to copy itself. Our goal is to block the virus from making copies by making a molecule that can change this bent structure. The design of my molecules was inspired by a natural product found in soil bacteria. Each new molecule synthesized is tested to see how it affects the bend within the viral IRES. The results help us to iteratively design new and improved molecules with the ultimate goal of finding a new medicine for HCV.

Through integrating the steps of the drug discovery process used in my research into a chemistry classroom activity, students are challenged to perform the various roles necessary for the development of new medicines. Students first identify disease-causing bacteria as the biological target. Using aspirin, a natural product, as the inspirational molecule, students are guided through a chemical synthesis where they change aspirin into a product called “oil of wintergreen.” Based on observations of physical properties before and after, students see evidence that a reaction has occurred and that their molecule has changed (solid to oil, bitter smell to minty smell, white color to colorless). The students then grow bacteria in the presence of the two different molecules, and observe the effect each molecule has on bacterial survival. No change in growth in the presence of aspirin illustrates that this molecule is not an antibacterial, but an area around the oil of wintergreen in which bacterial growth is prevented illustrates the effectiveness of oil of wintergreen in killing bacteria. These results help the students to further verify that their synthesis was successful and illustrates that even a small change in the structure of a molecule can lead to a medicine. Following the activity, students convene to discuss their results and talk about the importance of those results in light of the drug discovery process.

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Presenting Research in Acoustics to Students

Sound is important to everyday life and in particular, underwater sound is critical to many uses from Naval applications to oil exploration and biological studies. Understanding how sound travels in the ocean and interacts with its boundaries is the focus of this research, known as propagation modeling. For this research, acoustic transmissions are simulated through a horizontally layered environment that represents the ocean as a liquid, overlying a solid, which is the ocean bottom. The layers each have constant densities and sound speeds, dictating the speed at which acoustic transmissions travel through them. Symbolic software is used to calculate some constants. Then, using mathematical methods to evaluate an involved integral, the symbolic solutions are numerically analyzed using another program. In contrast to many other methods, the solutions we find provide exact solutions for the environment being modeled rather than an approximate one obtained by other methods. For instance, the ocean bottom is classically, and imprecisely, treated as a liquid. Once a solution is found and computed, it can be compared against other model and data sources for validation purposes. Another computed solution to compare against is that of an established model of the Pekeris waveguide (which has a similar configuration but uses a liquid bottom for simplification since a solid bottom is more difficult to deal with mathematically and numerically). The other comparison used to validate our model is against a set of experimental data taken in 2007 at the U.S. National Research Laboratory in Washington D.C. The experiment involved a water tank with a PVC slab (to represent the bottom) suspended in the water. A robotic apparatus took acoustic hydrophone measurements at constant depth and varying distance from a stationary source.

In bringing acoustics research into the classroom, different ideas of sound and sound propagation have been described. First, the ideas of waves and wave propagation were described to students in a solar experiment. Next, a cup phone experiment was performed, detailing the propagation of sound; specifically how sound travels through different media and loss mechanisms. Along with this, a slinky was utilized in order to describe the motion of the sound wave. Lastly, a lesson was developed in conjunction with a music teacher to present more of the musical side of sound. The math and science of acoustics were presented by GK-12 fellows, and this was followed by a musical lesson from the teacher. The experimental process was a major focus in the math and science portion, and steps taken in graduate research studies were described in terms of the experimental process.

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Targeting Pyruvate Carboxylase in Lung Cancer: Drug Development from the Laboratory to the Classroom

Lung cancer is the leading cause of cancer-related death in the US, and Kentucky leads the nation in lung cancer incidence and mortality. In an ongoing human patient study, our lab has discovered a potential lung cancer target-- pyruvate carboxylase (PC). PC is a mitochondrial enzyme that catalyzes the ATP-dependent carboxylation of pyruvate to form oxalacetate. We are seeking to 1) identify potential PC inhibitors from the ZINC drug-like database and 2) understand how these inhibitors affect PC activity, cancer cell growth and metabolism, and from that, develop a novel drug to treat lung cancer. To accomplish the first objective, we harnessed the computing power residing in Kentucky's K-12 classrooms. Over 13 million compounds were screened for binding at PC's active site using a structure-based virtual screening (SBVS) approach that involved a computer grid that tapped into thousands of computers throughout statewide public schools (work conducted by Dr. John O. Trent). The grid allowed the SBVS process, which would normally take hundred of years, to be completed in days. To accomplish the second set of objectives, we are linking modern metabolomics to traditional enzymology. Hits were purchased and their effects on PC activity were screened *in vitro* and *in situ*. Analysis of both assays relied heavily on enzyme kinetics. The *in vitro* assay coupled activity of purified PC or PC isolated from A549 lung cancer cells to malate dehydrogenase. The *in situ* assay used a stable isotope resolve metabolomic (SIRM) analysis where cells were given a 13C-labeled tracer such as glucose and the incorporation of the heavy label into various pathways was monitored over time using NMR and mass spectrometry. To date, we have verified *in vitro* and *in situ* PC inhibition by six compounds, demonstrated the compounds that inhibit cancer cell proliferation, and elucidated some of the downstream metabolic effects of PC inhibition.

How can Fellows meaningfully integrate such advanced research into a middle school science curriculum? We have developed a mini-unit that connects basic concepts in enzymology and the objectives of my research to foundational concepts our students learn in the FOSS "Chemical Interactions" and "Forces & Motion" modules. Key components of the mini unit include over-sized enzyme/substrate models that students can manipulate to illustrate how enzymes catalyze reactions based on the lock and key model. There is also a kinesthetic lab activity that demonstrates the effect of competitive inhibition on reaction rates followed by an activity where students use atom tiles to figure out products of a PC-catalyzed reaction. The unit ends with a student-led discourse where student groups use my research data to determine which of compounds among the SBVS hits are the "best new anti-lung cancer drug." This unit allows students to see how the fundamental concepts and skills we all learn in our middle school science class remain the driving force of today's research.

Social, Behavioral and Environmental

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Green Infrastructure: Evaluating a Novel Approach to Reducing Urban Flood Susceptibility

America faces a looming water infrastructure crisis. Nationwide, conventional urban and exurban storm water management systems increasingly require extensive replacement and repair, leaving residents susceptible to flood, infrastructure breakdown, and contamination risks. However, estimated U.S. stormwater system rehabilitation costs run in the billions, an expense that many municipalities are unable to afford. To address this problem, officials in several U.S and international cities are turning to an urban design-based alternative, termed green infrastructure, to supplement conventional surface and subsurface drainage systems. Based on core principles from landscape ecology, landscape architecture, and civil engineering, this green infrastructure approach purports to reduce flood susceptibility and reduce drainage infrastructure costs by decoupling runoff from existing stormwater management systems. However, relatively little scholarship has investigated these claims, and more thorough investigation of this novel strategy is required to advance its capabilities. To address this gap, this research will employ both empirical observation and modeling approaches--the Environmental Protection Agency-funded WinSLAMM (Source Loading and Management Model for Windows) and the Natural Capital Project's InVEST (Integrated Valuation System of Ecosystem Services and Tradeoffs)-- to predict current and future flood hydrology of several Pennsylvania sub-watersheds, quantify the infiltration capacity of pilot green infrastructure projects, and develop a comprehensive theoretical green infrastructure plan for an urban area that optimizes runoff capture and storm infiltration.

This research is being integrated into the Philipsburg-Osceola Area Junior High School in Philipsburg, PA, as one component of broad-based green design and engineering courses intended to teach students basic physical and engineering principles of urban hydrology, material flows, and energy. Students will engage with the Pennsylvania State University on field trips and will calibrate their findings with a plan for the design of their new school facility, a retrofit of the present Philipsburg-Osceola Area Elementary School.