Summer 2020 - Early Research Experience in E Term (EREE)

Students applying for the EREE program will indicate their top three (3) preferences from the following list of faculty projects.

Biology & Biotechnology

Deciphering the gut-brain connection- Reeta Prusty Rao
Understanding the neuronal connection between the gut and the brain in C. elegans, and how they learn to avoid foods that make them sick.
Project description: If you have ever had "butterflies in your stomach" you know that these sensations emanating from your gut suggest that your brain and gut are connected. The gut and the nervous system have a complex bidirectional communication. For example, patients with Alzheimer's disease (Haren et al., 2019) harbor abnormal microbiome or manipulation of patient diet to treat depression and anxiety (Slyepchenko et al., 2014).

Using C. elegans we will investigate the neuronal connections between the gut and brain that allow the animal to avoid foods (infectious agents) that make it sick. Specifically, we will investigate the role the gustatory neurons (ASEL and ASER), that is concerned with taste in avoiding ingestion of a fungal pathogen C. albicans. Using two behavioral assays, the lawn occupancy assay and a modified version of the binary choice assay we seek to establish that in the absence of the ASEL or ASER neuron C. elegans are unable to effectively detect that the fungal pathogen C. albicans is harming their gut post-infection. In wildtype C. elegans, C. albicans infection causes a distended gut and subsequent aversive behavior to the pathogen. We hypothesize that the ASE neurons mediate the aversive behavior. These behavioral experiments combined with molecular (life span assays) and genetic (mutant analysis) tools, we will probe the neuronal circuits between the gut and the brain. Since C. elegans faithfully recapitulates the anatomy, innate immunity and neuronal circuits of mammals, ultimately, this work will yield a deeper understanding of how the gut microbiome regulates behavior and mental health.
Prerequisites: Intro to Biotech

The impact of expression levels on mRNA stability in mycobacteria- Scarlet Shell
A student will engineer mycobacterial strains to experimentally measure the relationship between gene expression levels and mRNA degradation rates.
Project description: Mycobacteria include important human pathogens such as the bacterium that causes tuberculosis. These bacteria must regulate expression of their genes in order to survive the stressors that they encounter during infection. Gene expression can be regulated post-transcriptionally by regulation of mRNA degradation. However, the relationships between mRNA expression levels and mRNA degradation rates in mycobacteria are poorly understood. There is controversy in the scientific literature regarding these relationships in other bacteria as well. We will therefore design and perform an experiment to rigorously test the relationship

between expression level and mRNA degradation rates in the non-pathogenic model organism Mycobacterium smegmatis. An EREE student will design and construct reporter plasmids in which a gene encoding a fluorescent protein is transcribed from a promoter that can be controlled by addition of a drug. The student will establish drug levels that produce as wide a spectrum of expression levels as possible, then measure mRNA abundance, mRNA degradation rates, and protein abundance at each defined expression level. From these data, transcription rates and translation rates can be predicted computationally. The student will use the resulting data to define the relationships between transcription rate, mRNA abundance, translation rate, protein abundance, and mRNA degradation rate.
Prerequisite: BB2950 OR BB2003 OR BB3527

Biomedical Engineering

Using Crowding Techniques to Mimic the Structure of Pancreatic Tumors In Vitro- Catherine Whittington
This project focuses on combining various molecules with collagen materials on the benchtop to determine which combinations best mimic the structural organization of pancreatic tumors in the body.
Project description: This project explores various techniques that can be used to create experimental models of pancreatic tumors that have similar properties to tumor tissue within the body. These models are created on the benchtop (in vitro) to mimic what is observed in the body. Many models that are used to mimic pancreatic tumors have the right components found in tumor tissue in the body, but they do not have the same structures. In particular, we are interested in creating collagen-based structures that have a heterogeneous distribution of collagen fibers. One technique that we have started to explore is macromolecular crowding, in which we add molecules of various sizes and concentrations to collagen to crowd the collagen fibers in different ways. Once those molecules are added to our collagen, we test the materials to see how the molecules affect collagen stiffness, fiber organization, and degradation. We then compare our findings to what is observed in pancreatic tumor tissues in the body to determine which combination of materials we want to pursue for cell studies. For cell work, we can culture pancreatic tumor cells in our collagen-based materials to see how the cells grow and behave. The overall goal is to mimic what is see in pancreatic tumors in the body so that we can eventually use our models to predict how the tumors will grow and respond to drugs. Students will learn hands-on skills in biomaterial design, mechanical testing, degradation studies, microscopy, image analysis and possible cell culture depending on project direction and progress.
Prerequisites: None

Development of Functional Ultrasound Imaging of Brain- Haichong Zhang
The goal of the project is to develop the functional ultrasound imaging technology that quantify the blood volume and velocity of rodents.
Project description: The Medical FUSION lab is currently working on a project where a functional ultrasound device is used to image the coronal section of the brain. The project focuses on developing the algorithm that quantifies the blood flow of microvasculature which

represents the brain activity upon certain stimulation. While there currently exist methods to quantify and image hemodynamics of the brain such as fMRI or fNIRS, the use of ultrasound technology has the potential to provide the access to the improved spatial and temporal resolution in real-time and low cost. Functional Ultrasound (fUS) technology uses the principles of the doppler effect to produce an image which can detect the temporal tiny vibration and movement of tissue associated with blood flow, and particularly high spatial resolution is achieved by utilizing ultrafast plane wave image reconstruction which fires the acoustic wave in thousand Hz scale. The student will program the ultrasound research machine to collect the desired sequence data and develop the algorithm to extract the fUS information. The validation framework includes the vascular phantom study and the in vivo evaluation conducted on rodents. Ultrasound imaging is non-invasive and effective enough to pass through the thinner skulls of rodents. With the success of the project, visualization of brain velocimetry has a great impact on neuroscience research because it can be used to assess brain diseases and give us a better understanding of neural functions. We expect that this technology can be used to monitor the response of the brain upon pain and the effect of treatment.
Prerequisites: BME 1004

Investigating the biomechanical mechanisms of Calcified Aortic Valve Disease models integrating tissue engineering and high-resolution imaging- Kristen Billiar
Investigating the biomechanical mechanisms of heart valve calcification integrating tissue engineering models and high-resolution imaging.
Project description: Apoptosis is a part of the cell's life cycle. For numerous reasons, cells decide to suicide, i.e., apoptosis. During this procedure, the cells divide in smaller vesicles, which will be consumed by nearby cells, or cleaned up by the immune system. Even though there are multiple ways to clean the apoptotic bodies, some of them remain unremoved. These remnants later may cause unwanted changes, like calcification.

To study calcification, in this project, we will investigate the effect of mechanical loading on cells, in different models. The goal of this project is to investigate the calcification in single cells, and 2D aggregate models existed in our lab, for Valvular Interstitial Cells under static or dynamically loaded conditions. It will result in finding the relation between apoptotic bodies and the calcific nodules, by imaging them carefully, to investigate their colocalization.
Prerequisites: Stress analysis Mechanics, cell biology, with preferred/optional cell engineering lab and image analysis (ImageJ) experience

Chemical Engineering

Building and testing catalytic microreactors- Andrew R. Teixeira
Microreactors are the future of chemical synthesis; on this project you will help build and test new designs for catalytic microreactors.
Project description: Catalysts are used to speed up reactions, and microreactors are used to understand reactions. Together, they make a powerful tool for advancing our knowledge of how to make next generation renewable fuels and chemicals.

In this project, the student will work closely with a PhD candidate to construct tubular microreactors and test them for reactivity and common catalyst properties. They will participate in our summer group activities (research meetings, safety talks, group outings, etc.).
Prerequisites: None

Chemical Engineering & Humanities & Arts

Designing Hands-on, Context-Rich STEM Activities for Classroom Learning about Climate Change Mitigation- David DiBiasio & Kris Boudreau
Students involved in this project will work with faculty and graduate mentors to design, test, and improve a bench-scale model to be used in classroom settings to teach about carbon mineralization, a unique technology to capture and store carbon by using
Project description: This undergraduate research and design project will result in the prototype for a bench-scale model and curricular materials ("curricular kits") for secondary classrooms and WPI labs. Our research team is working with WPI STEM faculty, undergraduates, and Worcester Public School (WPS) teachers to provide to middle and high school classrooms and lower-level WPI courses the kind of experiential and integrative STEM + humanities learning that has been so successful in WPI's global IQPs. We develop models and curriculum that can be used in any classroom to approximate the learning experience of our global project centers ¬— designed to provide high-impact learning experiences for students who cannot travel to project sites. All of our curricular kits involve science and technology applied to a particular problem in a specific site, and all provide both relevant hands-on STEM learning and the cultural and historical context in which technology is implemented. The centerpiece of our curricular kits is a bench-scale model that can be used to demonstrate and test engineering ideas. Our first prototypes have been piloted in WPI classes and will soon be piloted and assessed in WPS.

The project we propose here teaches climate change mitigation. One of the many ways to deal with increasing atmospheric CO2 levels is carbon capture and storage. We propose a bench-scale model to simulate a unique technology, carbon mineralization, to capture carbon by using naturally occurring alkaline rock formations or other feed stocks such as mine processing waste. Prof. Jen Wilcox's lab is conducting research in this area in collaboration with a national leader in the field, Dr. Peter Keleman of Columbia University:

https://www.nytimes.com/interactive/2018/04/26/climate/oman-rocks.html

A field test site has been established at Tower Hill Botanical Gardens, which is a popular site for school field trips and will be integrated into a curricular kit.
Prerequisites: None

Designing Hands-on, Context-Rich STEM Activities for Classroom Learning about Threatened Communities and Climate Change Refugees- Kris Boudreau & David DiBiasio
Students involved in this project will work with faculty and graduate mentors to design, test, and improve a bench-scale model to be used in classrooms to teach climate change in threatened indigenous coastal communities.

Project description: This research and design project will develop a bench-scale model and curriculum for secondary classrooms and WPI labs. Our research team is working with WPI STEM faculty, undergraduates, and secondary school teachers to provide classrooms with the experiential and integrative STEM + humanities learning that characterizes WPI's global IQPs. Our curricula apply science and technology to a particular problem in a specific site, providing both relevant hands-on STEM learning and the cultural and historical context in which technology is implemented. The centerpiece is a bench-scale model to demonstrate and test engineering ideas —in this case, what happens to threatened communities suffering in specific ways the global effects of climate change. Prototypes have been piloted in WPI classes and will soon be piloted and assessed in WPS.

Rising temperatures leading to ice melt and rising sea levels threaten traditional life for indigenous populations, particularly in polar areas where communities depend on the marine environment for their ways of life. Existing curricular materials regarding climate change lack the context-rich, societal focus we believe is critical to integrative and deep learning. Our kit will be situated in a threatened Native Alaskan community, such as Kivalina, likely North America's first climate change refugees. The context includes native history, customs (including storytelling), personal narratives, local economics, and politics. It might include a 3D print of an endangered location with houses, people, animals, and local geography. That physical map will sit in a contained water environment, where water level changes showing erosion and flooding can be induced with a simulated sun (like a heat lamp) under "normal" (pre-global warming) conditions and then under simulated greenhouse gas, enabling students to learn about thermal expansion, radiative and conductive heat transfer, and simple fluid flow in concert with cultural topics, including local agency and community empowerment.
Prerequisites: None

Chemistry

Synthesis of New Pthalimide-based Radical Abstractors- Patricia Musacchio
Research with the Musacchio group will involve synthesis of novel phthalimide-based organic compounds for testing as reagents that accomplish CH functionalization using photoredox catalysis.
Project description: Research in the Musacchio group is focused on developing new organic chemistry transformations. The goal is to use our transformations to improve the synthesis of small molecules, and therefore speed up the drug discovery process which on average takes 12 years. We are currently working in the area of CH functionalization using novel phthalimide-based compounds as precursors to oxygen-centered radicals to achieve the CH activation. The undergraduate student would spend the summer assisting our team in synthesizing the novel phthalimide-based organic compounds . The student will get to test out the success of their new compounds as new reagents for accomplishing CH activation under our reaction conditions. In addition, the project involves activation of the phthalimide-based compounds via the use of visible light catalysis.
Prerequisites: CH2310, 2320, 2330

Chemistry & Biochemistry

Cisplatin Resistant Cancer Therapies Inspired by Phomoxanthone A- Anita E Mattson
Cisplatin resistant drug development and biomolecular target identification using phomoxanthone A.
Project description: Cisplatin resistant cancer is cause for great concern in the context of cancer therapy. Natural products provide inspiring starting points for the development of new therapeutics able to treat cisplatin resistant cancers. Specifically, in the project, phomoxanthone A will be used to initiate the discovery of a new small molecule therapeutic with a unique mode of action. The investigator will assist in the synthesis of phomoxanthone A analogs and the study of the biomolecular target of phomoxanthone A.
Prerequisites: Organic chemistry lecture and lab

Characterization of phosphoinositide domain stability- Arne Gericke
Characterization of phosphoinositide domain stability
Project description: Lipids are a class of biomolecules that affect or even control virtually all processes that occur on cellular membranes and are thus very important for cell physiology and human biology. Biological membranes are bilayers of lipids. The two leaflets of the bilayer have not only different overall lipid composition but also different lateral composition; each leaflet contains domains that have distinct lipid compositions and physical properties. Different proteins are attracted to these domains because they bind to specific lipids enriched in the domain and/or because the domain provides a physical environment suitable for specific protein association. As a result, lipids and proteins form supramolecular structures that are platforms for a multitude of important cellular functions, most notably cell signaling. The Gericke research group investigates whether the domains situated in the two opposing bilayer leaflets line up ("register") with each other and if so, whether the two domains situated in register physically affect each other. The group also examines how proteins interact with domains situated in contact with different domains in the opposing leaflet and how they affect the lipid composition of the domains. These experiments aim to answer the pressing question how cellular signals originating from domains on one side of the lipid bilayer elicit responses in domains in the opposing leaflet. Phosphoinositides (PIPs) are important lipidic signaling molecules that affect an extraordinary array of protein functions. Dysregulation of PIP levels and/or an incorrect spatial distribution of these lipids have been associated with a broad range of disease states, most notably neurological diseases, diabetes type II and cancer. The undergraduate student will investigate the thermal stability of phosphoinositide enriched domains in model systems. The aim is to determine how the stability of these domains is affected by their respective composition and the interaction with PIP binding proteins.
Prerequisites: CH1010, CH1020, CH1030

Porous MOFs as host materials for molecular storage and separation- John C. MacDonald
Development of porous metal-organic frameworks (MOFs) as host materials for molecular storage and separation.

Project description: Porous metal-organic frameworks (MOFs) consisting of crystalline coordination polymers are of interest as host materials for molecular sorption, storage, and release. MOFs exhibit permanent porosity, high thermal stability, and feature channels with high surface areas, large pore volumes, and properties that can be tailored through synthesis. We currently are exploring strategies to trap molecular guests inside MOF particles and subsequently trigger their release in an effort to develop porous materials suitable for applications involving storage and controlled delivery of molecules (e.g., drug delivery, sensors, devices, reactions, separations, smart materials, etc.).

Toward those goals, the work in this project will focus in the following areas: (1) synthesis of several porous MOFs and characterization of their structure, porosity and stability; (2) examination of the sorption-desorption behavior of native, unsealed MOFs toward molecular guests (organic dyes) in solution; (3) investigation of the ability of sterically demanding trapping agents to coordinate to the surface of MOF particles and inhibit diffusion of guest dyes out of MOFs; (4) development of labile trapping agents that can be removed in response to physical or chemical stimuli (light, chemical reagents, changing pH or temperature, etc.); and (5) investigation of solution-based synthetic methods to generate and control the size of MOF particles.
Prerequisite: Organic Chemistry

Development of non-clogging inks for printable, flexible semiconductors for solar energy absorption- Ron Grimm
Development of non-clogging inks for printable, flexible semiconductors for solar energy absorption.
Project description:
Our group has a collaboration with the Rao group in Mech. E. to develop non-traditional solar absorbers and electrical contacts for flexible solar cells. We would like to print solar cells with inkjet printers, but even the most "printable" solar materials tend to clog print heads.

Our idea is that rather than printing the semiconductors, the printers deposit the precursors to the desired materials that yield solar absorbing semiconductors directly on the substrate of interest. This involves finding combinations of precursors that are compatible with inkjet printing, and solvents that have low enough vapor pressures to survive for a sufficiently long time to sustain synthesis in the deposited droplets but high enough vapor pressures or solubility to ultimately be removable following synthesis.

A successful outcome would enable flexible electronics for sensor, solar cell, and LED applications.
Prerequisite: Second-year CBC lab track (Ch 2640-2670)

Synthesis of thin film BiOI- Ron Grimm
Students will synthesize and characterize thin-film bismuth oxyiodide that is relevant to the production of inexpensive tandem-junction solar cells.

Project description: Students will synthesize thin-film bismuth oxyiodide as might occur in the production of solar cells. As this material is not well understood, students will pay particular attention to the ways in which changes in growth condition lead to different doping profiles, electronic structure, and surface defects.
Prerequisite: Second-year chemistry or chemical engineering lab classes

Computer Science

Developing and Studying Novel Sign Language Technology- Erin Solovey
This project takes a human-centered computing approach to build a foundation that advances understanding of how deaf individuals could work and learn in environments that are designed with their needs and preferences at the forefront.
Project description: We are looking for motivated students to work with us on exciting research on accessibility of information for deaf individuals. This interdisciplinary project would provide opportunities for students interested in human-computer interaction, accessibility, Deaf education, and user interface design.

Members of the Deaf Community whose first or primary language is American Sign Language (ASL) currently engage with interactive computer tools presented exclusively in English, including those designed expressly for ASL content and educational materials. The lack of ASL-based navigation is in part due to the fact that the signed languages of the world have unique requirements that do not align with existing text-based user interface design practices. Therefore, the development of Sign-Language First (SL1) technology offers great promise for ASL-signing users and others interested in signed language content. SL1 design has the potential to level the playing field for deaf students seeking to access academic, linguistic, and other informational content online.

In this project, students will explore previously developed and novel approaches that will allow users to engage with technological tools through a signed language with no reliance on conventional written language. To that end, all aspects of a user interface, including menus, search tools, and navigation buttons, be presented visually. The research team will look at the feasibility of incorporating photos, videos, illustrations, and characters representing the linguistic features of ASL vocabulary, such as handshapes, movement patterns, and location (i.e., placement on the signer's body).
Prerequisite: No. Fluency in American Sign Language would be an asset, but it is not required.

Integrating Non-Invasive Neuroimaging and Educational Data Mining to Improve Understanding of Robust Learning Processes- Erin Solovey
This project combines computer science and neuroscience tools to study whether a computer could detect a person's cognitive state while using an interactive computing system.
Project description: We are looking for motivated students to work with us on exciting research on brain and body sensing and brain-computer interfaces, and applying them to interactive educational systems, medicine, and user experience research. This interdisciplinary project would provide opportunities for students interested in human-computer interaction, brain-

computer interfaces, emerging sensor platforms, psychology, cognitive science, machine learning, data science, machine learning, feature selection, signal processing, and information visualization.
Prerequisite: None

Computer Science & IMGD

Analysis of Quilting as a Metaphor for Computer Programming- Gillian Smith
Improving computer science education for the general public through creative applications
Project description: Quilting has often been used as a metaphor for computer science education in K-12 contexts. Researchers and educators have used construction instructions as a metaphor for procedural execution of code, and block patterns as a metaphor for classes and objects. The underlying geometry of quilt construction has also been studied as a way to teach variables and function parameterization.

We are working on a project for teaching computer programming to adult quilters, and finding that the metaphor used in K12 education (where the students are typically learning about quilts alongside learning about computing) breaks down breaks down when used with established quilters. We posit that this is because quilters think about their own creative practice very differently than computer scientists do, and prioritize different aspects of quilting than the mathematical or procedural.

In this research project, students will analyze existing data we have from interviews and a three hour focus group with quilters that were focused around what they prioritize in their hobby, and their opinion about computer science and use of computers. The goal is twofold:

a) to study where quilting works as a metaphor for computing, and where it fails; and

b) to develop a set of guidelines for how quilters think about their own process that will be used in making better computational tools for quilters.
Prerequisite: None required; it would be helpful if they have taken an introductory programming course (high school or college level), but do not need to have strong programming skills.

Data Science

AutoCNNs: Automated CNN Architecture for Early Detection and Classification of Skin Cancer over Dermoscopic Image Analysis- Chun-Kit Ngan
We develop an automated CNN architecture that assists physicians in early detecting skin cancer over dermatoscopic image classification.
Project description: Skin cancer is the most common cancer in the United States. According to American Academy of Dermatology Association, there are approximately 9,500 people in the U.S. diagnosed with skin cancer every day. To support the early detection and diagnosis of skin cancer, dermatoscopy is a widely used technique, as dermatoscopic images have an immense

potential for the detection of a suspicious mole at the earliest stage. However, for physicians to early detect and classify a skin cancer into a specific type, such as melanoma, melanocytic nevus, basal cell carcinoma, actinic keratosis, and benign keratosis, is very challenging due to various subjective and time-intensive interpretations.

To address the above issues, deep learning approaches, mainly convolutional neural networks (CNNs), have played an important role to speed up the early detection of skin cancer through the dermatoscopic image classification. Using this state-of-the-art technology to support the early detection of skin cancer, physicians find a better way to treat their patients for this cancer more effectively and efficiently. The more effective and efficient detection and diagnosis improve the survival rate of patients. Thus, we are interested in studying and exploring more about this technology that not only addresses human health issues but also improves our horizon in the collaboration of clinical diagnosis and computer vision.

To achieve the above objectives, we propose to develop an automated CNN architecture that assists physicians in early detecting skin cancer over dermatoscopic image classification. Specifically, the contributions of this work are three-fold: (1) provide the user-friendly web interface to physicians to diagnose the skin cancer on those images; (2) develop an automated pipeline to early detect and classify the cancer; and (3) conduct the experimental study, using the dermatoscopic images provided by the International Skin Imaging Collaboration, to present the classification result in terms of accuracy performance.
Prerequisite: Any courses related to python and any software development platform, deep learning, image analysis and processing, etc.

Fire Protection Engineering

Characterizing vegetation for modeling wildland fire spread- Albert Simeoni
How does vegetation burns in wildfires?
Project description:
This work will cover different aspects of how vegetation contributes to fire spread:
- How to characterize the vegetation properties as input of models of fire spread.
- How to characterize the interaction between vegetation on flow (wind or buoyant plume).
- How to characterize heat transfer in vegetation from a flame front (convection and radiation).
- How to process data in a format that is adequate for fire spread modeling.
- How to design an experiment and acquire data for fire spread modeling.

Experimental work will be conducted in the FPE laboratories in FPE's wildland fire research group, led by prof. Simeoni. The experimental work will cover one or more of the following aspects: conduct measurements of vegetation properties, measure flow in a wind-tunnel, conduct burning experiments of vegetation elements (including setting up probes and measurement devices), process experimental data, format data for fire models.
Prerequisite: None

An Imaging-based Wildfire Detector for First Responders- James Urban
The goal of this project is to develop image analysis software to detect and make automated measurements of a wildfire from images taken with a smart phone's camera.
Project description: This project will develop the necessary image processing software to allow a smartphone to be used as a wildfire detector and tracker for use in wildland-urban interface (WUI) fires. The common scenario of WUI fires is a wildland fire encounters an urban area such as housing development. A challenge for first responders is tracking the fire front which is important for preventing them from being trapped by the fire, but also affects how they direct evacuees. Providing firefighters and other first responders with tools to improve their situational awareness would help them save lives, including their own.

Networked sensor packages distributed in wildland areas near the perimeter of urban areas could provide early fire detection and warning to first responders and residents and allow for the spread of the flame front to be tracked. Smartphones provide an attractive platform to develop a prototype, because they are equipped with a power source, network capabilities, camera hardware, and some computational resources.

The goal of this project is to develop novel software which can process raw images taken from a smart phone camera and automatically 1) identify regions containing flames and 2) determine their size (height & width) and distance from the camera, based on a depth and spatial calibration of the field of view. The software will be tested with laboratory experiments with a linear burner simulating a wildland fire front.
Prerequisites: A 1000 level CS course

Humanities and Arts

Design and Social Justice: Engineering Ethics in a New Key- Yunus Dogan Telliel
This project is a study of contemporary engineers' views on ethical and social implications of design.
Project description: From the envisioning of future technologies and their social implications, to the challenges of usability in an increasingly diverse society, design in engineering exceeds pure technicity. This project looks at the rise of a new way of thinking about ethical design in global engineering communities. This new way reflects a growing concern among engineers that the code of ethics, although indispensable to a professional occupation such as engineering, might not be sufficient to fully address questions of social equality, cultural diversity, and environmental justice. As such, some engineers have suggested that engineering ethics moves its focus from the individual engineer's intentions and responsibility to an awareness of social injustices that engineering projects are (unintentionally or not) creating or furthering. In this project, we ask the following questions: How do engineers define design? When and how do they acknowledge design's dual nature (the technical and the social)? Is the social implication of design mainly an afterthought? Do engineers turn their conversations on design into a site for ethical reflection on probable consequences of technological innovation and implementation?
Prerequisites: None

IGSD/Global School

Leveraging Artificial Intelligence and Machine Learning to Support Vulnerable Populations- Sarah E. Stanlick

This project is focused on exploring the ethical, technical, and health implications of artificial intelligence and machine learning to support vulnerable populations such as multigenerational families and refugee communities.

Project descriptions: I am currently working with a large, multisite hospital system in Pennsylvania – St. Luke's University Health Network – on a Microsoft AI for Good grant focused on how we might use machine learning and AI tools to support grandparents who are raising their grandchildren/great-grandchildren. The toll of opioid abuse, incarceration, and family separation has led to large number of unexpected situations where grandparents become the head of household. With that burden, we hypothesize that the health and wellbeing of these grandparents becomes more complicated and often worse. There is pre-existing research that indicates challenges of increased social isolation, mental health (including depression and anxiety), and poor health outcomes due to a decreased attention to chronic conditions and personal physical health. This experience also matches very closely the experience of intergenerational refugee families coming to the United States. Isolation, culture shock, integration, and support form a complex web of challenges for our new neighbors. Our goal would be to improve reporting, management, connecting to social services, and assessment of patient health and wellbeing leveraging the Microsoft Azure platform. Artificial intelligence and machine learning can serve as a support by connecting families to resources, recognize warnings, and analyze data that provides insights into their lives and needs. This support could lead to better health outcomes, social cohesion, reduced medical costs, and a more thriving population of multigenerational or newly arrived families. Research questions include: 1.What opportunities exist to leverage artificial intelligence to support families in vulnerable circumstances and address their health and wellbeing? 2.Do different modalities in AI and machine learning (e.g. cognitive services, facial recognition, etc.) have impacts on addressing the health and wellbeing of vulnerable populations?

Prerequisite: None

Materials Science & Engineering (Mechanical Engineering)

Materials Science Characterization of Additively Manufactured Material- Danielle Cote

Materials science characterization of additive manufacturing material for a project with the U.S. Army Research Laboratory.

Project description: Gas-atomized metallic powders are commonly used as feedstock material in additive manufacturing processes. Research has shown that the chemistry and microstructural properties of the feedstock powder can significantly affect the properties of the consolidated material. Thermal treatment and recycling parameters for powders used in both solid and liquid state processes can further affect the microstructure and properties of the consolidated parts. Understanding the powder microstructure and effects of powder pre-treatment can aid in optimizing the properties of the final consolidated part. This research

proposes a method for the characterization and optimization of powder pre-processing parameters utilizing thermodynamic and kinetic modeling as guidance using aluminum alloy powder as examples. Light microscopy, electron microscopy, and hardness were used to evaluate each condition and validate the thermodynamic and kinetic predictions.

Summer Research:
Advanced characterization techniques will be utilized to fully understand the microstructural evolution of the feedstock powders. These techniques include:
•Optical microscopy of loose, mounted, etched, and unetched powder
•Scanning electron microscopy (SEM) of loose, mounted, etched, and unetched powder
•Nanohardness of loose, mounted, etched, and unetched powder
•Secondary phase analysis via microstructural analysis software
•Sample preparation
•Differential scanning calorimetry (DSC) testing and analysis
Prerequisites: ES2001 (preferred, not required)

Mathematical Sciences

Packings and Coverings in Finite Groups- Padraig O Cathain
This project will explore subsets X of a finite group with the property that every non-identity element in the group can be represented in at least (or at most) one way as a product of two elements from X.
Project description: In Euclidean geometry, given a line 'L' and a point 'p' not on that line, there exists a unique line parallel to 'L' which contains 'p'. Projective geometry differs from Euclidean geometry in that there are no parallel lines: every pair meets in a unique point.

Projective planes with finitely many points have many applications in algebra, combinatorics and discrete mathematics. Unfortunately, they seem rarely to exist. This project will introduce students to difference sets, which are algebraic analogues of projective planes. Students will then explore Sidon sets (packings), and partial difference sets (coverings) which generalisations of difference sets, currently of active interest in the combinatorics community.

It is likely that a good student could make a publishable contribution in this area over the course of eight weeks, while gaining research experience in combinatorics and algebra.
Prerequisites: At least two of MA3823, MA3825, MA2271, MA2273, MA2073. The most desirable courses are listed first.

Mechanical Engineering

Separating materials in a multi-material composite- Brajendra Mishra
Using chemical methods to separate ceramic coated metallic materials for full recycling of spent composite materials.
Project description: The post-consumer multi-material scrap needs to be sorted and separated to determine the most effective and efficient process for remanufacturing of engineering

components. Most of today's products are made of multiple materials so a product-centric view of recycling will be adopted in this project. After optimized sortation and separation of scrap product, the concept of process design for remanufacturing from scrap will be explored with actual test results and material-process-property relation will be predicted for the final remanufactured alloy. High strength base metals and alloys are widely employed in high temperatures and other extreme environment applications such as in firearms and gas turbine engines. Such materials are coated with protective coatings to provide protection of metal substrates from degrading environments and thereby increase service life. Several layers of coatings may be applied to base metal substrates consisting of different materials including ceramics, refractory, metallic or composite materials, depending on the particular application. In this project chemical and electrochemical methods will be employed.

The coatings on metal substrate can be oxidized and degraded by exposure to a suitable stripping composition. A selective stripping agent must be selected which is selective to coating and inert to substrate. The stripping composition generally consists of oxidizing agent and strong acids where the choice and concentration of stripping chemical depends on the type of coating with minimal damage to substrate material. The exposure of stripping solution to coated material facilitates oxidation, formation of cracks and to some extent penetration to the interface between coating and substrate which causes internal stresses to develop in coating material for easy removal. In electrochemical method, the difference in electrochemical potentials of coating and base metal is used for the separation process by selective dissolution of the coating when immersed in a stripping solution.
Prerequisites: ES 2001 and high school chemistry

Atherectomy-Grinding in Human Artery- Yihao Zheng
Perform hands-on experiments on a medical device that goes into arteries, pulverize blockages, restore blood flow, and treat cardiovascular diseases.
Project description: Atherectomy, an interventional cardiology procedure, uses a high-speed grinding wheel to remove hardened, calcified plaque inside arteries, restore the blood flow, and treat cardiovascular diseases. During atherectomy, a small diamond grinding wheel rotates up to 210,000 rpm to pulverize the plaque into fine debris absorbable by the blood and vessel. The grinding wheel is driven by a flexible drive shaft enclosed in a plastic sheath. The grinding wheel and drive shaft rotate around and translate along a guidewire which is non-rotational. Saline flows through the sheath for lubrication and cooling of the rotating drive shaft. Blood flows outside the sheath and carries the debris into the human circulation system. The material removal mechanism, including the grinding wheel motion and force, is critical to atherectomy performance. Excessive grinding force may lead to vessel damage or downstream occlusion by large debris.

This study experimentally investigates the grinding wheel motion and force, ground surface, and debris size in atherectomy. Grinding wheel motion and force will be measured using high-speed camera and piezoelectric dynamometer, respectively. The ground surface will be examined by confocal microscopy. The debris size will be analyzed by a laser diffraction particle

size analyzer. The experiment will be based on a phantom block simulating the human artery tissue property and blood flow.
Prerequisites: None

Cardiovascular Medical Simulation- Yihao Zheng
Design and fabrication of a medical simulation station for the cardiovascular system based on human anatomy and physiology.
Project description: This is a hands-on project to build a medical simulation station for the human cardiovascular system. A cardiovascular simulator will be established based on human anatomy and physiology. This simulator will allow testing and clinical training of interventional medical devices. The student will design the simulator based on patient medical image data (provided), literature review, and computer-aided design software. The student will build this simulator utilizing additive manufacturing, soft-tissue mimicking material molding,, and machining.
Prerequisites: None

Microstructure Analysis of Aluminum-Based F-state Alloys- Yu Zhong
The students will get a chance to go through the typical procedure of making Al alloys and getting in touch of our novel design strategies.
Project description: The heat treatment of die-cast pieces is costly and can lead to unwanted blistering and distortion. Aluminum alloys that do not require post-solidification heat treatment benefit from both shape retention and excellent surface finish. The current project focuses on the exploration and development of an F-state (as-cast) aluminum alloy via high-pressure die casting (HPDC) that meets certain specifications. As a case study, the team will use the commercial 518Al alloy to see how to improve its castability without significant change of its other properties.
Prerequisites: ES2001

Cellphone Based Imaging Module for Noninvasive, Portable, and Accessible Blood Tests- Yuxiang Liu
This project aims to develop modular, accessible, and portable imaging devices for non-invasive blood tests.
Project description: A blood test is a routine blood analysis in health care. Most blood tests, such as white blood cells measurements, require a visit to a healthcare center and are performed by trained clinical professionals, limiting the accessibility especially in resource-limited regions. Blood sampling for blood tests nowadays still need venipuncture, which involves pricking the skin with a sharp object. Such processes result in pain, possible infections, sterile requirements on the equipment and environments, and impact on life quality for special patient groups, such as cancer patients receiving chemotherapy due to the need of frequent blood tests. This project aims to develop modular, accessible, and portable imaging devices for non-invasive blood tests. Such devices can be clamped on a common smartphone to serve as a microscope and to capture videos of the blood vessels below the nail, without the need of pricking the skin. The expected results include a ready-to-use cellphone clamp with an integrated imaging system and mechanical fastening mechanisms, the real-time measurements

of the concentration of white blood cells in any patients, and a possible scientific journal publication. The obtained results will be used to extract external funding from both the government and industry to continue the project after summer. The future work include the design of a batch fabrication process, development of a cellphone app for real-time video analysis with patient-friendly result display, and clinical trials with a large group of cancer patients. The final goal of the project is to benefit the masses by commercialization of such devices and by including other blood test capabilities such as glucose monitoring.
Prerequisites: No courses are required. Good hands-on skills, patience, and dedications are essential to the success in this project. Any design or manufacturing experience and optical system design will be helpful.

Physics

Controlling the activity of the active fluid with temperature using temperature-dependent DNA hybridization- Kun-Ta Wu
Utilize DNA to engineer nanoscale molecular motor proteins so as to control the macroscopic millimeter-scale turbulent-like mixing flow of microtubule-based active fluid.
Project description: Active fluid liberated from equilibrium constrain is capable of performing the task beyond the limit of conventional passive fluid such as self-transporting cargos from Point A to Point B. This capability has been used in numerous applications such as molecular shuttles, optical devices and parallel computation. However, to bring the application to the next level requires the ability to control the active matter in situ. Previously, we used Arrhenius characteristic of the active fluid to control the fluid speed with temperature. However, such a controlling method could only tune the fluid speed in a limited range: 4–8 μm/s; the method was unable to cease the flow, i.e. 0 μm/s. To expand the controllability, we propose to redesign the power source of the active fluid: molecular motor proteins. In the active fluid system, the motors were dimerized to drive pairs of microtubules whose motion stirred the surrounding liquid to cause fluid flows. The flow could be ceased manually if the motor dimers could be disintegrated into monomers in situ. To reach this goal, we aim to conjugate the motor proteins with DNA, allowing for dimerizing the motors using DNA hybridization. Since DNA hybridization is thermoreversible, the motor dimerization is expected to be controlled with temperature. We expect that this work will enable us to accelerate and decelerate the flows of active fluid manually like a gas pedal of a car.
Prerequisites: No but a passion toward the fundamental science is prerequisite.

Optical properties of 2D materials- Lyubov Titova
Optical and electronic properties of two-dimensional materials studied used ultrafast optical techniques.
Project description: Carrier confinement in one or more dimensions, high surface/volume ratio, and reduced dielectric screening give 2D materials their unique optical and electronic properties. In this project, a student will learn how to characterize properties of 2D metals like MXenes and 2D semiconductors like SnS2 or MoS2 using ultrafast optical techniques.
Prerequisites: PH1111/10, PH1120/21, PH1130

Robotics Engineering

Making surgical lasers learn to cut better – Loris Fichera
We will experimentally study the interactions between a surgical laser and biological tissue, and attempt to use machine learning models to model these interactions.
Project description: The research objective of this project is to investigate new techniques to enable surgical laser systems to intelligently learn the optimal dosimetry parameters to best cut any type of biological tissue. We envision the creation of smart surgical laser systems able to characterize its interaction with an unknown tissue type by delivering a number of interrogation pulses and then use this knowledge to synthesize an appropriate controller for cutting that tissue. We are currently recruiting an undergraduate research assistant for the summer of 2020 to assist with the execution of controlled laser experiments, and the collection/analysis of microscope images. The project will be carried out in the COMET lab, located within PracticePoint.
Prerequisites: No. Candidates should preferably be majors in either BME or RBE.

Social Sciences and Policy Studies & Data Science

Refining Methodologies and Applications of Privacy Management in Ghana- Robert Krueger and Randy Paffenroth
This project will examine the role of context in shaping data collection.
Project description: Research in the global space requires a careful understanding of the context of where we work and where technology is deployed. This notion is reaching more and more technological applications in the developing world. From typeface, to user experience with Apps, and using drones to deliver medical supplies researchers, companies, and governments are gaining a better understanding of how innovations in science, technological design, and implementation differ from place to place. There is still more work to be done.

WPI researchers have examined critical differences between the inspiration for and application of science and technology in Africa and Europe and North America. Data Science has offered little guidance in this area. Without identifying existing and previously untapped, unique databases African policy makers and companies cannot effectively develop and integrate appropriate solutions.

We will explore the link between context and data collection and analytics in the nation of Ghana. In 2019, Ghana was the fastest growing economy and keeps a wide range of transactional, environmental, and socio-economic data. This makes Ghana a great candidate for this study.

To begin this work we are focusing on the ethics of data collection with a special interest in privacy. The goal of this project is twofold. We will:
1) identify the privacy concerns that Ghanaians have over their personal information, and,
2) develop data collection strategies that respect these privacy concerns.

Specifically, we will start by examining point- of-sale data through passive and active data collection. In addition to WPI researchers our collaborators in Ghana are interested in these questions. We also have partners in high-level positions at Vodaphone's Mobile Money Division who handle point of sale transactions.

This is phase I of a larger project that could expand into IQPs, MQPs, and beyond.
Prerequisites: Some knowledge of data science and computer science

Sensing applications- Doug Petkie
The development of millimeter-wave sensor technologies, the study of the associated phenomenology, and experimental validation.
Project description: The student will join or help initiate one of projects in the lab based on their interests. We utilize the same technology (see skills) for many different topics. Projects include the use of a radar system to measure micro-Doppler signatures of human gait and vital signs for remote identification of activities or triage/sensing applications. Subsurface imaging for non-destructive evaluation that can look for manufacturing defects, porosity in rocks for the oil industry, monitor moisture content in drying, or even for medical applications. Gas phase molecular spectroscopy to monitor the environment or for health applications such as breathe analysis. Materials studies for to support devices for the above applications (i.e. adsorption of gasses in 2D materials or optical properties of materials for imaging).
Prerequisites: None. We can adapt the project and provide training as needed.