Summer 2021 – Early Research Experience in E-Term (EREE)

INSTRUCTION FOR STUDENTS:

- Find your top three (3) projects that you would be most interested in working on
- Search by faculty name or discipline, or just browse through
- Use the table of contents to help you navigate
- When you are done, choose 3 of your favorite project ideas
- In the application you will need to indicate these three (3) projects

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AEROSPACE ENGINEERING

Design and modeling of origami structures with tunable mechanical properties

Advisor: Zhangxian Yuan, zyuan2@wpi.edu

One-sentence description: Development of origami structures for higher loading carrying capabilities.

Project description: Origami, the ancient art of paper folding, is now sparking a scientific revolution. The origami family (foldcore) offers a wide range of unit cell geometries with tunable mechanical properties. For example, Miura-ori, a 3D object, is created by folding a 2D sheet and has excellent properties, such as a negative Poisson's ratio. Therefore, a series of novel structures can be developed by adopting different types of origami patterns and geometry configurations. The student will build these prototypes, test their loading carrying capabilities, develop finite element models, and perform structural analysis to simulate the mechanical behavior.

Skills the student will learn: The student will get a chance to go through the typical procedure of structural analysis and gain hands-on experience in developing origami structures.

Mentoring plan for the student: I will have weekly meetings with the student and provide supports that he/she needs.

Prerequisites: None.

BIOLOGY & BIOTECHNOLOGY

Epigenetic Engineering

Advisor: Amity Manning, almanning@wpi.edu

One-sentence description: This project combines molecular and cellular biology approaches to engineer new human cell lines that will be used to gain a better understanding of how chromosome structure is regulated during cell division.

Project description: The structure and compaction of the genome is tightly regulated by epigenetic mechanisms to allow for dynamic gene expression and chromosome segregation. Defects in the process or proteins that reversibly regulate chromatin compaction can lead to DNA damage and whole chromosome segregation errors during cell division. Such changes, termed genomic instability, underlie human diseases like cancer where they contribute to high mutation rates and tumor cell evolution. Because chromatin compaction is a dynamic process that changes through the cell cycle and is differentially regulated at distinct parts of each chromosome, it has been difficult to experimentally manipulate and define the function of key regulators of this process. This project will use genetic engineering to create constructs that, upon drug induction, will use CRISPR-based approaches to tether epigenetic regulators of interest to defined regions of the genome. Cell biological and imaging-based approaches will be used to validate construct expression in cell culture and to begin to define the impact of the tethered epigenetic regulator on genome stability.

Skills the student will learn: This project will use molecular biology approaches including: primer deign, PCR-based amplification, gel extraction, restriction enzyme digestion and ligation to generate expression constructs for individual epigenetic regulators. Cell biological approaches will be used to genetically engineer human cells to carry and express the constructs generated. Fluorescence microscopy and image analysis techniques will be used to validate the cell lines generated and begin to characterize the role of each epigenetic regulator in the regulation of genomic stability.

Mentoring plan for the student: The student will work closely with a graduate student in the lab- first working together to learn techniques and then progressing towards parallel research where the grad student mentor will meet at the start of each day to go over experimental plans and then remain available for questions/assistance as the student implements their plans. The student will meet with me individually weekly (or more often as needed) to discuss progress and ensure conceptual understanding. The student will also attend weekly lab meetings (where grad students present their work and/or relevant literature is discussed).

Prerequisites: BB1035 Intro to Biotechnology, and/or BB2550 Cell Biology.

BIOLOGY & BIOTECHNOLOGY

The consequences of mutations in mycobacterial RNases

Advisor: Scarlet Shell, sshell@wpi.edu

One-sentence description: This project combines molecular biology and genetics to investigate how mutations cause drug resistance in the bacteria that cause tuberculosis.

Project description: Tuberculosis, caused by the bacterium Mycobacterium tuberculosis, kills 1.4 people each year. Drug resistance rates are rising, making TB treatment more difficult. Whole genome sequencing has revealed mutations associated with drug resistance in various M. tuberculosis genes. For many of these mutations, the functional consequences and relationship to drug resistance are unknown. In summer 2021, 1-2 EREE students will investigate the consequences of a mutation reported in RNase E in a clinical M. tuberculosis strain. This mutation is surprising and interesting for two reasons: (1), mutations in RNase E have not been previously associated with drug resistance, and (2), the mutation is predicted to cause loss of function of an essential gene. The students will use the non-pathogenic model organism Mycobacterium smegmatis, which can be handled safely and has an RNase E gene very similar to that of M. tuberculosis. The students will genetically engineer M. smegmatis to contain the resistance-associated mutation in RNase E, as well as other mutations predicted to have similar effects on RNase E function. They will then determine the impact of these mutations on growth rate, mRNA degradation rates, and drug sensitivity. The resulting data will shed light on the function of an essential process in mycobacteria, mRNA degradation, and the relationship between this process and drug resistance. The project is ideal for one or two students.

Skills the student will learn: The students will learn how to design site-directed mutagenesis constructs and primers, use PCR and molecular cloning to make the constructs, culture E. coli and mycobacteria, use phage integration sites to make mutations in essential genes, measure gene expression and mRNA degradation rates by quantitative PCR, measure bacterial growth kinetics and stress tolerance, and measure drug sensitivity. In the process, the students will also learn how to design experiments with proper controls, troubleshoot failed experiments, use statistical analysis software to analyze their data, and interpret their data. The students will also further their professional development by learning how to read primary literature, contextualizing their research question within the field, presenting their experiments and data in lab meeting, and working within an externally funded research lab where projects are driven largely by graduate students and postdocs.

Mentoring plan for the student: I will introduce the student(s) to the overall idea of the project and place it into context within the other projects ongoing in the lab and the field more broadly. I will meet with the student(s) at least once a week to discuss their experiments and progress and help with troubleshooting and data interpretation and contextualization. Ying Zhou and Julia Ryan will provide daily mentoring to the student(s) in the lab, with the help of other lab members including my two postdocs. Most of the projects in the lab are interrelated and most lab members regularly perform core techniques such as PCR, cloning, mycobacterial culture, quantitative PCR, drug sensitivity testing. We therefore have a lab culture in which all of the senior lab members are available on an as-needed basis to help and advise undergraduates. I will provide the EREE student(s) with journal articles related to their project and meet with them to discuss the articles and how they relate to our work. We have weekly lab meetings in which lab members take turns presenting their data and relevant articles from the primary literature. The EREE student(s) will attend lab meeting weekly and present their own project at the end of their research experience. Most of the lab will (virtually) attend a regional conference called the Boston Bacterial Meeting on June 10-11, and the EREE student(s) will attend as well.

Prerequisites: BB2950 Molecular Biology and/or BB2003 Fundamentals of Microbiology (for conceptual background on molecular biology and microbiolgy), as well as at least one biology lab course (for basic lab skills).

BIOLOGY & BIOTECHNOLOGY

Variability of S. aureus Infection in C. elegans

Advisor: Jagan Srinivasan, jsrinivasan@wpi.edu

One-sentence description: How does infection affect our ability to smell?

Project description: As we've been seeing with the SARS-COV2 pandemic, to the same infectious agent people can have different reactions ranging from asymptomatic to severe infections. In the round-worm Caenorhabditis elegans, we have been investigating the neurological challenges the worms face during Staph, S. aureus, infection. We have seen that from the same time-course of infection, worms can have different physiological responses; some are totally deficient in their brain activity while others can still respond to their environment. This project will investigate why there are differences in infection responses, both physiologically and behaviorally, and whether the worms can recover from the infection to regain their physiological/behavioral activity. First, the behavior of the worms will be investigated at different timepoints of infection to observe the differences in the movement of the worms across time. With several infection timepoints of interest, we will look at the physiological response of the worm's neurons towards a strong repulsive cue. With the combination of behavior and physiology, we can see if there is a connection seen in the activity of the worm's behavior and the activity of the worm's neurons. Are some worms more robustly responding against infection? Lastly, we will investigate the ability for the worms to recover after infection. We will infect the worms for different amounts of time, test their behavior, and then allow them to recover, after which point we will test the behavior and physiology of these particular worms. What we will start to uncover is whether the worm's response after infection is intrinsically linked with the worm's ability to recover after infection.

Skills the student will learn: The student will gain the experience of molecular biology and behavioral biology. The student will also learn statistical methods that are required to analyze behavioral data and also learn to present presentations to the group.

Mentoring plan for the student: Research mentoring plan: Looking into the response to infection from a neurological perspective, we will investigate how worms have differences in reactions from infection and whether they can recover from it. The student will be exposed to the different behavioral assays. We will initiate a discussion process and introduce the student to the behaviors. then we will try and introduce the problem. Research mentoring Outline: Infected worms have variability in the severity of infection effects (difference in movements and neuron activity) at the same point of time of infection. Student will be asked these initial questions: Why is there variability (in physiology and behavior)? In behavior: look at speed of worms and body bends. In physiology: look at activity of sensory neurons response to 1M glycerol after infection. Then, we will proceed to ask the following questions: Can they recover? After a specific timepoint of infection, test behavior. Then allow worms to recover for some time: 24hours. Test behavior of worms again- speed, body bends. See if their neurons can regain their activity back to 1M glycerol. Data analysis: The student would be able to analyze and interpret the data and deduce conclusions.

Prerequisites: None.

BIOMEDICAL ENGINEERING

Investigating the biomechanical mechanisms of Calcified Aortic Valve Disease on a chip

Advisor: Kristen Billiar, kbilliar@wpi.edu

One-sentence description: This project involves analysis of how mechanical forces regulate Calcified Aortic Valve Disease using tissue engineering models, cell culture, and quantitative image analysis.

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 are not removed. 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.

Skills the student will learn: None, but stress analysis/mechanics, cell biology, cell engineering lab and image analysis (ImageJ) experience preferred.

Mentoring plan for the student: Each undergraduate who works in our lab is mentored by a graduate student. They develop a mentor-mentee contract (project description, time expectations, how they'll communicate, etc.). All trainees (from postdoc to high school) attend weekly lab meetings which consist of discussion of lab issues, data presentation, and journal club. J-club presentations rotate between all lab members.

Prerequisites: None.

BIOMEDICAL ENGINEERING

Using Tissue Engineering Strategies to Mimic Tumors and Lymphatic Environments In Vitro

Advisor: Catherine Whittington, cfwhittington@wpi.edu

One-sentence description: This project focuses on using a combination of techniques and tissue engineering strategies to determine biomaterial conditions needed to generate experimental models that more accurately mimic the tissue surrounding tumors and/or lymphatic vessels.

Project description: This project explores various techniques that can be used to create experimental models of pancreatic tumors and lymphatic vessels 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 in vitro models that are used to the body's tissues the right components, but they do not have the same type of tissue organization or stiffening capabilities. We are interested in creating collagen-based samples that have a heterogeneous organization of collagen fibers and/or the ability to stiffen over time. We have started to explore two techniques to the organization of fibers in our samples. One approach is macromolecular crowding, in which we add molecules of various sizes and concentrations to collagen to crowd the collagen fibers in different ways. The other method is to embed collagen fibers within another material to change the organization of fibers on the material surface. To alter sample stiffness over time, we use a specialized form of collagen stiffens when exposed to certain types of light. In all cases, we test the samples to see the effects on material stiffness, fiber organization, and material degradation. We then compare our findings to what is observed in the body's tissues (normal and diseased) to determine which combination of materials we want to pursue for cell studies. For cell work, we can culture tumor cells or lymphatic cells on or within our samples to see how the cells grow and behave. The overall goal is to mimic what is seen in the body so that we can eventually use our models to predict how tumors and lymphatic vessels grow in diseased states and how they might respond to drugs.

Skills the student will learn: Students will learn basic laboratory skills related to: biomaterial design, mechanical testing of soft materials, degradation studies, microscopy, image analysis and possible cell culture depending on project direction and progress. Students will also learn data analysis and basics in statistical testing and data presentation. In addition, we will work on scientific communication through writing and oral presentation. We will also reinforce policies related to academic integrity and responsible conduct of research and help ensure that students are good laboratory citizens.

Mentoring plan for the student: The EREE student will be mentored by a graduate student in my research laboratory under my overall supervision. The EREE student, graduate student, and I will meet at the start of the program to discuss mentorship and expectations for their time in the research group. The three of us will also have regular meetings in addition to the regular research group meetings with all research students. The EREE student will also be included in all research group activities, including social activities. It is important to me that the EREE student has a true research experience, so I will ensure that they have their own project that integrates with an existing project in the research program. They will start the program with by completing all necessary training to work safely in the research laboratory prior to being trained on skills that are specific to my research laboratory and their project. Our laboratory space is open concept, which fosters a collaborative environment, so the EREE student will be introduced to other researchers who work in the same area. Finally, I work to make sure that I am available to all of my trainees by email, Slack, or one-on-one meetings. I will ensure that the EREE student knows that I am accessible to them as a resource and will set-up regular one-on-one meetings to check on their progress and overall satisfaction with the experience. We will make adjustments as needed to help the student have the best possible overall experience.

Prerequisites: None.

BIOMEDICAL ENGINEERING

Investigating drug bind and release to biomaterials for cancer treatment

Advisor: Jeannine Coburn, jmcoburn@wpi.edu

One-sentence description: The goal of the project is to develop and investigate biomaterial-based drug delivery systems for cancer treatment.

Project description: The Coburn lab develops drug delivery systems for cancer treatment. We utilize two biopolymers for this purpose, silk fibroin and chondroitin sulfate. These biopolymers can be modified to alter the drug binding and release. The student will investigate how drugs bind to and release from these biomaterials for applications in cancer treatment. Experiments will be performed to further our understanding of the binding mechanism and allow us to identify new approaches to alter the drug release kinetics.

Skills the student will learn: The student will gain experience in biomaterial formation, basic chemistry techniques, drug delivery formulations and analysis of drug delivery using uv-vis spectroscopy, data analysis and interpretation, and, when appropriate, software-based statistical analysis.

Mentoring plan for the student: The student will work directly in the lab to perform research tasks. The graduate student mentor and I will develop the initial research plan that allows the student to gradual become independent. The undergraduate student will attend Coburn lab group meetings throughout their summer experience and be expected to present their initial research plan and a final presentation of their summer project. The Coburn lab will provide academic and career mentoring as well.

Prerequisites: None.

BIOMEDICAL ENGINEERING

Assessment of the behavioral and neural activity changes in a nematode traumatic brain injury model

Advisor: Dirk Albrecht, dalbrecht@wpi.edu

One-sentence description: This project aims to develop sonication as a repeatable form of mild TBI and assess how various injury parameters (magnitude, duration, frequency) affect live brain activity and behavior in the C. elegans model.

Project description: How mild traumatic brain injury (TBI) affects neural function is currently unknown. Students will collect data on spontaneous and stimulus-evoked behavioral and neural responses of C. elegans to varying levels of mechanical injury by sonication. These experiments use microfluidic devices for precise environmental control and will analyze conditions that lead to the physiologic changes consistent with traumatic brain injury. Live brain activity is recorded using microscopy and optogenetic reagents already established in the lab. The results of this project will inform future work in studying effects of injury timing and magnitude, neuroprotective processes and therapies, and the genes and biochemical pathways that affect neural responses following mechanical injury.

Skills the student will learn: The student will learn nematode culture, microfluidics, lab automation, microscopy, image processing, and data analysis.

Mentoring plan for the student: The student will join as a full lab member, including daily interaction with the mentoring graduate student and weekly lab meetings and PI interaction, as needed. The student will be encouraged to present results in a lab meeting and externally, either in the Undergraduate Research event or an external research conference (such as BMES).

Prerequisites: No, but familiarity with basic wet lab skills use of programming environments (MATLAB) are useful.

BIOMEDICAL ENGINEERING

Optimization of Deep Brain Stimulation (DBS) parameters to alter neural and behavioral responses in a nematode model

Advisor: Dirk Albrecht, dalbrecht@wpi.edu

One-sentence description: This project aims to determine deep brain stimulation parameters that increase and decrease neural responses and assess resulting behavioral effects in normal C. elegans and a model of Parkinson's disease.

Project description: Deep Brain Stimulation is an effective tool to restore neural function in patients with neurological disorders. Currently, stimulation parameters such as frequency, pulse duration, voltage, and polarity are determined empirically for each patient, and mechanisms of action are not well understood. This project aims to systematically evaluate parameters that increase or decrease neural activity, using a recent MQP project capable of delivering precise electrical stimulation to C. elegans contained within microfluidic devices. Expanding on prior results, the student will run DBS stimulation experiments with a wide range of frequencies, duty cycles and stimulation voltages using the power supply and electronic equipment provided. Live brain activity is obtained by microscopy, and data will then be analyzed using existing methods to determine neural responses under a variety of conditions.

A successful project will identify DBS parameters that alter live neural activity under normal conditions. Extended experiments would examine the effect of DBS on a Parkinson's disease model, both neural activity and locomotory behavior.

Skills the student will learn: The student will learn nematode culture, microfluidics, lab automation, microscopy, image processing, and data analysis.

Mentoring plan for the student: The student will join as a full lab member, including daily interaction with the mentoring graduate student and weekly lab meetings and PI interaction, as needed. The student will be encouraged to present results in a lab meeting and externally, either in the Undergraduate Research event or an external research conference (such as BMES).

Prerequisites: Circuits (BME2210 or ECE2010) is helpful background, and familiarity with basic wet lab skills and use of programming environments (MATLAB, ImageJ) are useful.

CHEMICAL ENGINEERING

Flow Chemistry for Pharmaceutical Manufacturing

Advisor: Andrew Teixeira, arteixeira@wpi.edu

One-sentence description: Microfluidics and flow chemistry are the future of pharmaceutical manufacturing; this project will have you design, build and test microreactor technology to be used by real industry teams at pharmaceutical companies.

Project description: The pharmaceutical industry is undergoing two major shifts: 1) biologics and 2) personalized medicine. The former uses large macromolecules as thereputics and the latter requires rapid, on demand synthesis of custom drugs. This project addresses a major gap in our manufacturing capabilities by developing technology (flow chemistry) to translate our antiquated commercial batch synthesis operations (reactors, separators, mixers) to continuous flow. This will make them smaller, more flexible, higher purity and much more efficient. The specific project will involve constructing reactors (connecting tubing, fittings, pumps, heaters, etc.) and testing them under simple conditions (e.g. alcohol separation or hydrogen peroxide decomposition). It is supported on an external grant with AIChE RAPID and the ACS GCI Pharmaceutical Roundtable.

Skills the student will learn: Strong interest in tinkering/problem solving in lab. Interest (but no prior knowledge) in computer programs (Excel, Matlab) will help for data analysis. Interest (but no prior knowledge) in automation/robots could be interesting (LabVIEW to control).

Mentoring plan for the student: We will have weekly group meetings where the EREE student will be expected to present a literature review and an end of summer research update. The student will also be required to participate in weekly subgroup meetings to present progress to myself and select graduate students. On a day-to-day basis, they will report directly to the graduate student to ensure productivity in research.

Prerequisites: None.

CHEMICAL ENGINEERING

Automating Lab Processes in Synthetic Biology

Advisor: Eric Young, emyoung@wpi.edu

One-sentence description: Use robots to automate key steps in the process of genetically engineering microorganisms.

Project description: Synthetic biology is changing the world. In the Young Lab, we genetically rewire microbes to make interesting compounds. Because we don't understand everything about how life works, this usually involves trying many variations of genetic designs and iterating to reach an optimal design. For researchers in our lab, this means lots of pipetting. Many of the repetitive steps we carry out have been successfully automated (to various degrees) within our lab and elsewhere. We currently have two liquid handling robots; a Labcyte Echo for handling very small volumes (25 nL) and an Opentrons OT-2 for handling "large" volumes (50-1000 uL). We would like a summer researcher to focus on automation of several routine lab tasks, including minipreps, NGS library prep, PCR, and cloning. Successful completion of each task automation will involve understanding the task to be automated, researching current successful methods, understanding the appropriate robot, designing protocols for both the user and the robot, and providing an assessment and recommendation for scale efficiency and waste. If you are looking for a project that involves both programming and wet lab research, this would be a fit for you.

Skills the student will learn: Understanding of basic biochemistry techniques (minipreps, NGS library prep, PCR, cloning), laboratory automation experience, Python programming language.

Mentoring plan for the student: The student will be mentored by Kevin Keating, who is familiar with the project and can guide the student in terms of overall goals as well as day-to-day troubleshooting. Kevin will orient the student to the lab and the project, and provide training on the techniques to be automated and the use of the robot. Once the student is progressing independently, Kevin will check in with the student 2-3 times a week to review progress and help with troubleshooting.

Prerequisites: None.

CHEMICAL ENGINEERING & HUMANITIES & ARTS

Designing Hands-on, Context-Rich STEM Activities for Classroom Learning about Threatened Communities and Climate Change Refugees

Advisor: Kris Boudreau and David DiBiasio, kboudreau@wpi.edu and dibiasio@wpi.edu

One-sentence description: Students involved in this research 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: Our interdisciplinary research seeks to bring hands-on, context-rich, and historically accurate STEM activities into middle/high schools and WPI classrooms. Research indicates that STEM activities involving real communities have a powerful influence on recruiting and retaining under-represented groups in STEM, while also enhancing learning outcomes for all students. The UN's Intergovernmental Panel on Climate Change warned that people have already been born who will face a "very high risk" of famine, water scarcity, and mass vegetation die-offs if the trajectory of global warming is not reversed. More recently, the UN Human Rights Committee ruled that governments must take into account the human rights violations caused by the climate crisis. Rising temperatures leading to ice melt and rising sea levels threaten traditional life for indigenous populations, particularly in polar areas where communities live off the marine environment. Existing curricular materials regarding climate change lack the context-rich, societal focus we believe is critical to integrative and deep learning. Students involved in this research will work with faculty to design, test, and implement a bench-scale model to be used in classrooms to teach climate change in threatened indigenous coastal communities. Our work focuses on 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 enabling students to learn about thermal expansion, heat transfer, and fluid flow in concert with cultural topics, including local agency and community empowerment. Other kits might investigate other advanced mitigation technologies such as carbon sequestration, mineralization, direct-air, forest, and ocean capturing.

Skills the student will learn: Library/database research, Application of research, Basic fundamental research standards and methods, Ethics and social impacts in research, Techno-economic analysis, Site visits: observation, listening, interviewing, Use of analytical equipment, including some of the following: spectrophotometry, gas chromatography, GIS mapping, 3-D printing, videography, Teamwork, Technical communication with non-technical audiences, Curriculum development and learning theory and applications, Building models, Prototyping, testing, refining, Engineering design, Opportunity to co-author and/or present research papers and posters.

Mentoring plan for the student: Under the mentorship of Professors Boudreau and DiBiasio, the summer research intern will help design, develop, and test a kit (module) and associated curricula for middle school and higher levels that demonstrate the effects of climate change on threatened communities. Boudreau and DiBiasio will mentor the student in the science of climate change and the design of a bench-scale model to demonstrate its effects. Professors Boudreau and DiBiasio will mentor on prototyping, testing, and curriculum development, including the cultural context of the community and themes of social justice. The student will join a team of undergraduates currently working on other curriculum kit design and testing, and the different teams will have a weekly meeting with Boudreau and DiBiasio, who will also be available for daily consultations. Weekly team meetings will be used to guide the student in forming research questions, finding sources, understanding school learning standards, and designing, building, and testing a prototype. The student will also have access to a machinist and an electrical engineer in the Goddard Hall labs.

Prerequisites: None.

CHEMICAL ENGINEERING & HUMANITIES & ARTS

COVID and Cholera: The Human Technology of a Pandemic

Advisor: David DiBiasio and Kris Boudreau, dibiasio@wpi.edu and dibiasio@wpi.edu

One-sentence description: Students involved in this research will work with faculty and graduate mentors to design, test, and improve a bench-scale model to be used in classrooms to teach the human and technological consequences of a pandemic.

Project description: Our interdisciplinary research seeks to bring hands-on, context-rich, and historically accurate STEM activities into middle/high schools and WPI classrooms. Research indicates that STEM activities involving real communities have a powerful influence on recruiting and retaining under-represented groups in STEM, while also enhancing learning outcomes for all students. This research addresses the human and technical issues of the COVID pandemic through the lenses of history and math. We start Dr. John Snow's legendary ghost map, the first use of social and scientific data to resolve an epidemic (cholera in 1856 London). Background activities drawn from the NSF's BioED site include a Ghost Map reconstruction and an exercise about molecular dispersion in air. We extend this to today's pandemic and more challenging math, e.g. predicting virus spread using the COVID exponential growth model. That allows students to understand how assumptions, statistical variations and uncertainty in data (various reductions in the infection factor) affect predictions and actions. The primary hands-on activity is to build a home version of the coughing mannequin using readily available materials to visualize aerosol dispersion and quantify the pattern's persistence and dispersion. Then, using an age-appropriate air dispersion model (ALOHA) used by the EPA (EPA, 2020) and adopted for virus dispersion in a room, students test and quantify how different initiations like a sneeze or heavy cough affect the viral dispersion cloud. These tools, integrated into an extended project, are personalized by applying them to a student's home, a social gathering, a classroom, an athletic event, or a favorite restaurant (e.g. researching virus spread as a function of ventilation patterns and person location). This engages students in challenging decisions about managing individual and group human behavior as a function of confidence in the data and the models. Results could be pooled to examine community implications and policy.

Skills the student will learn: Library/database research, Application of research, Basic fundamental research standards and methods, Ethics and social impacts in research, Techno-economic analysis, Site visits: observation, listening, interviewing, Use of analytical equipment, including some of the following: spectrophotometry, gas chromatography, GIS mapping, 3-D printing, videography, Teamwork, Technical communication with non-technical audiences, Curriculum development and learning theory and applications, Building models, Prototyping, testing, refining, Engineering design, Opportunity to co-author and/or present research papers and posters.

Mentoring plan for the student: Under the mentorship of Professors DiBiasio and Boudreau, the summer research intern will help design, develop, and test a kit (module) and associated curricula for middle school and higher levels that demonstrate the effects of virus epidemiology in social and human contexts . DiBiasio and Boudreau will mentor the student in the science of pandemics and the design of a bench-scale model to demonstrate its effects. Professors DiBiasio and Boudreau will mentor on prototyping, testing, and curriculum development, including the cultural context of the community and themes of social justice. The student will join a team of undergraduates currently working on other curriculum kit design and testing, and the different teams will have a weekly meeting with DiBiasio and Boudreau, who will also be available for daily consultations. Weekly team meetings will be used to guide the student in forming research questions, finding sources, understanding school learning standards, and designing, building, and testing a prototype. The student will also have access to a machinist and an electrical engineer in the Goddard Hall labs .

Prerequisites: None.

CHEMISTRY & BIOCHEMISTRY

Passivation of Cesium Titanium Bromide

Advisor: Ron Grimm, rlgrimm@wpi.edu

One-sentence description: Passivation of Cesium Titanium Bromide with ALD-Deposited Titanium(IV) Oxide

Project description: Cesium Titanium Bromide was identified by our group and others as a compelling earth-abundant, non-toxic solar energy absorber but our recent results have demonstrated it is not air stable. We have developed a method for synthesizing it and then passivating it against decomposition using atomic layer deposition. An interested student would use these tools to determine the best passivation strategy that yields high-quality thin film material with high stability in the air. The outcome of this project would be a stable, high-performing, earth-abundant, non-toxic, fifth adjective for kickassness semiconductor for efficient, inexpensive tandem-junction solar cells. Try saying that ten times quickly.

Skills the student will learn:
- Nanoparticle synthesis
- Secondary derivitization of particle surfaces for fun and profit
- Material characterization (X-ray diffraction, photoelectron spectroscopy)
- Understanding of safety considerations when working with dangerous chemicals

Mentoring plan for the student: Daily conversations, weekly group meetings. Students are slotted into a collaborative, supportive research environment where everyone shares their successes and failures, and we all try to keep everyone's work moving forward. This is not a fringe project where students are off on their own, but a critical part of our larger research program. Students are equal partners in the success of the research efforts.

Prerequisites: None.

CHEMISTRY & BIOCHEMISTRY

Synthesis of of Titanium Oxycarbide Nanoflakes for Hydrogen Production

Advisor: Ron Grimm, rlgrimm@wpi.edu

One-sentence description: Synthesis and Characterization of Titanium Oxycarbide Nanoflakes for Hydrogen Production.

Project description: Recent results from Michel Barsoum at Drexel in collaboration with Lyuba Titova's lab and our group have yielded layered nano flakes of titanium, carbon, and oxygen that show incredibly high catalytic production of hydrogen (water splitting) but we have absolutely no idea what their structure is or the synthetic mechanism that yields these nanoflakes! Students on this project will undertake a series of experiments to figure out how this reaction proceeds and how we might manipulate the reaction to control particle size and other effects of reaction temperature, starting reagents, etc. The outcome of this project should be a deeper understanding of how to make the best possible hydrogen production catalysts that can complete with platinum on performance but for significantly less $$. This is critically important to moving away from fossil fuels and changing the world!

Skills the student will learn:
- Nanoparticle synthesis
- Secondary derivitization of particle surfaces for fun and profit
- Material characterization (X-ray diffraction, photoelectron spectroscopy)
- Understanding of safety considerations when working with dangerous chemicals

Mentoring plan for the student: Daily conversations, weekly group meetings. Students are slotted into a collaborative, supportive research environment where everyone shares their successes and failures, and we all try to keep everyone's work moving forward. This is not a fringe project where students are off on their own, but a critical part of our larger research program. Students are equal partners in the success of the research efforts.

Prerequisites: None.

CHEMISTRY & BIOCHEMISTRY

Zirconium MOFs for Drug Delivery

Advisor: Shawn Burdette, scburdette@wpi.edu

One-sentence description: This project merges concepts of coordination chemistry with analysis of crystalline materials to create water-stable metal-organic frameworks (MOFs) with potential applications in drug delivery.

Project description: Metal-organic frameworks (MOFs) have the capacity to encapsulate guest molecules and store a large amount in small crystals. Capping groups can seal a guest molecule inside a MOF. We are adapting earlier work with zinc MOFs, which are unstable in water, to a zirconium UiO-66, which is very robust, by exploring alternative strategies to the ionic bonds used previously. UiO-66 is prepared by solvothermal methods and we are currently trying to grow larger crystals to facilitate investigation of the surface interactions that allow sealing of the MOF channels by capping groups. In addition, we are expanding up a strategies to link the capping groups through the formation of silicon-oxygen bonds. In parallel we will be quantifying the amount of model drug molecules can be absorbed into the UiO-66 structure as well as the range of sizes of guest molecules that can be efficiently loaded into the MOF.

Skills the student will learn: Solvothermal synthesis of crystalline materials, Thermogravimetric analysis of MOF stability, Power X-ray diffraction for characterization of crystal lattices, UV-vis analysis of guest capture and release, Surface modifications of MOFs by wet synthetic methods, X-ray photoelectron spectroscopy for analysis of MOF crystal surfaces.

Mentoring plan for the student: All students participate in weekly groups meetings where experimental results from the previous week are discussed and analyzed. Students will meet individually with me on a regular basis, and students will be assigned supplemental readings from the literature related to their project. The MOF subgroup works closely with one another with experiments being performed in parallel with different materials, or slightly modified procedures. Research results are documented at the end of the summer in a report and poster where I provide feedback about content and presentation.

Prerequisites: None.

CHEMISTRY & BIOCHEMISTRY

Thermal stability of phosphoinositide signaling platforms

Advisor: Arne Gericke, agericke@wpi.edu

One-sentence description: Thermal stability of phosphoinositide domains

Project description: This project is related to an NSF funded grant that is aimed at characterizing phosphoinositide lipid domains and gradients in biological membrane mimics. The importance of phosphoinositide lipids for cell physiology and human biology cannot be overstated since they affect or even control virtually all processes that occur on cellular membranes. Biological membranes are lipid bilayers with different lipid compositions in the two bilayer leaflets. At the same time, the respective lipid bilayer leaflets exhibit lateral inhomogeneities, termed domains, which have distinct lipid compositions and physical properties. Proteins are attracted to these domains because they bind to specific lipids within the domain and/or the domain provides for a physical environment that is suitable for 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. Dr. Gericke's research group investigates whether the domains in the two opposing bilayer leaflets line up ("register") with each other and if so, whether the physical properties of the two domains affect each other. This EREE summer project is aimed at characterizing the thermal stability of phosphoinositide domains using infrared and fluorescence spectroscopy. Phosphoinositide domain stability will be investigated in the presence of varying charged chemical species like calcium cations and cationic peptides.

Skills the student will learn: The EREE researcher will be trained in the handling of in a variety of basic biochemical laboratory techniques, including the handling of lipid and protein samples. In addition, the undergraduate researcher will use advanced infrared and fluorescence spectroscopy.

Mentoring plan for the student: The student will work alongside other undergraduate students, graduate students and postdocs in my lab. In addition to the EREE activities, the student will be able to participate in the departmental REU activities (I am the PI of the CBC NSF-REU grant). I am planning to be in the lab myself as time permits and work with my undergraduate students throughout the summer.

Prerequisites: CH1010 through CH1040.

CHEMISTRY & BIOCHEMISTRY

Lipid Analysis of Parkinson's Disease Models in C elegans

Advisor: Carissa Olsen, cpolsen@wpi.edu

One-sentence description: Using mass spectrometry to analysis the membranes of Parkinson's Disease mutations

Project description: Membranes are the lipid bilayer that separates cells from their environment. In addition to forming this barrier, membrane lipids also play key roles in energy production, signaling and regulation. The membrane is composed of hundreds of different types of lipids and the overall membrane landscape impacts its properties and function. In the Olsen lab, we use stable isotope labeling to track how membrane lipids are made and replaced over time. To do this, we use a model organism called C. elegans which allows us to quantify membrane dynamics in mutants or in conditions that mimic human diseases using mass spectrometry. In this study, we aim to analyze the membranes of models of Parkinson's Disease and, in doing so, lay the foundations for improved detection and for the development of novel therapeutics.

Skills the student will learn: This project will teach students how to work with mass spectrometry which is a method is commonly used for the detection of small molecules like lipids. Additionally, the student will learn how to culture nematodes and monitor their phenotypes. Specifically, students will gain the following skills: GC/MS and HPLC-MS/MS, Nematode growth and maintenance, Lipid extraction and analysis, Participation in group meetings, Data analysis and presentation.

Mentoring plan for the student: The student will work side by side with a graduate student through all the method development and techniques. In addition to casual chats, I will meet with them formally once a week as well as their participation in weekly group meetings. This is a collaborative group, and there will be graduate students and undergraduates in the lab to help them succeed in their growth as scientists and in their project.

Prerequisites: None.

CIVIL, ENVIRONMENTAL & ARCHITECTURAL ENGINEERING

Bioinspired Concrete Elements

Advisor: Nima Rahbar, nrahbar@wpi.edu

One-sentence description: A new paradigm in reinforcing concrete

Project description: Concrete has the greatest, most wide-spread usage of any construction material. However, concrete is inherently brittle and practical use of concrete require use of tensile reinforcement. For the last century, typical tensile reinforcement in concrete has been placed as steel bars either parallel or perpendicular to the long direction of the structural elements. Inspired the deformation and toughening mechanisms in nacre, and significant progress in the field of additive manufacturing, the inner layer of abalone shell, in this project, reinforcing concrete with metallic foams will be investigated. Our preliminary results on 10 PPI, 20 PPI, and 40 PPI 6106-T6 aluminum foams and stainless steel A16 fibers were used as reinforcement in 1″ x 1″ x 1″ cubes of cement paste and cured for 14 days before tested in compression. The preliminary results show that this configuration of reinforcement materials have a synergistic effect on reinforcing the cement paste and altering the composite structure can yield a stronger concrete material. The results show that these composite samples were able to withstand significantly higher stresses than typical control samples of reinforced concrete. Beyond the foam samples, the steel fiber composites produced an average ultimate stress that was less than the ultimate strength of the control samples but was still better than the yield stresses of the 20 and 40 PPI foam-cement paste samples. Out of the reinforcement concrete composites examined, the 10 PPI aluminum foam proved to be the best reinforcement option. During summer, I propose to further advance this concept by the use of cold spray process. Metallic structures will be designed and additively manufactured using the cold sprayed process. The printed structure will be used as the reinforcement in concrete. The undergraduate students will work along an outstanding graduate student with multiple high-quality publication, Shuai Wang, to advance this project.

Skills the student will learn: The student will learn basic and intermediate concepts in theoretical and applied mechanics concepts, intermediate to advance numerical simulations, and be exposed to extensive mechanical testing of solids.

Mentoring plan for the student: I have a strong track record in mentoring undergrads in summer. Since joining WPI in 2012, I have at least hosted 2 undergraduate students in my lab. All of these students have been integrated to the activities in the lab, and successfully presented their findings at the end of the summer. Many have now successfully joined the workforce, attend medical school or joined grad schools such as MIT. For this project, the undergraduate student, similar to previous years, will work closely with the graduate student, Shuai Wang, an outstanding PhD student with multiple high quality publication, under my supervision, learn the skills and develop an understanding for research in materials science of composite materials, and structural mechanics .

Prerequisites: Mechanics of materials. Basic physics.

COMPUTER SCIENCE

A New Kind of Thinking Cap: Using Brain Imaging to Improve Human-Computer Interaction

Advisor: Erin Solovey, esolovey@wpi.edu

One-sentence description: 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 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.

Skills the student will learn: Key learning objectives include gaining an understanding of interdisciplinary human-computer interaction research methods, experience developing robust software following current best practices in software engineering, exposure to machine learning methods and training in experimental design and analysis. Depending on student background and interests, the project may involve investigating the architecture for robust fNIRS analysis tools, following current best practices in software engineering (Java, Python, Matlab, D3, Javascript, HTML, CSS) to enhance our testbed and dashboard for data processing and visualization. It may also involve conducting literature reviews, user interface design, and coordinating experiments with human subjects to advance human-computer interaction research. In addition, the project may focus on exploring machine learning approaches to classify brain data in real time or statistical analysis (Matlab,SPSS, Excel) and other analytic work on offline data sets.

Mentoring plan for the student: First and foremost, I encourage all of my students to come talk to me at any time for any reason, including work/research related reasons, career advice, mentoring, etc. Students will have a weekly meeting with me to discuss their research progress and any obstacles encountered. The students will also attend all-hands project meetings and gain experience in having research-related discussions and coordinating activity amongst a larger team. Through the process of supervised research, independent work, regular one-on-one meetings, and weekly lab meetings, the students will become an integral part of the research group and will gain insight into the related research conducted at WPI. The process of designing and running experiments, working with collaborators, collecting and analyzing data, presenting the work at conferences and ultimately helping in writing a research publication will all serve as excellent experiences for the students. My research group currently is made up of three PhD students, and several undergraduate students. In addition, the research group shares the physical lab space with four other research groups, all of which conduct research in human-computer interaction. Therefore, there would be opportunities to meet other undergraduate and graduate students in the area of human-computer interaction. The students will be provided with a workspace in the lab.

Prerequisites: None.

COMPUTER SCIENCE

Developing and Studying Novel Sign Language Technology

Advisor: Erin Solovey, esolovey@wpi.edu

One-sentence description: 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).

Skills the student will learn: Key learning objectives include gaining an understanding of interdisciplinary human-computer interaction and accessibility research methods, experience developing user interfaces and robust software following current best practices in software engineering, and exposure to American Sign Language. It may also involve conducting literature reviews and coordinating studies and interviews with human subjects to advance the research.

Mentoring plan for the student: I encourage all of my students to come talk to me at any time for any reason, including work/research related reasons, career advice, mentoring, etc. Students will have a weekly meeting with me to discuss their research progress and any obstacles encountered. The students will also attend all-hands project meetings and gain experience in having research-related discussions and coordinating activity amongst a larger team. Through the process of supervised research, independent work, regular one-on-one meetings, and weekly lab meetings, the students will become an integral part of the research group and will gain insight into the related research conducted at WPI. The process of designing and running experiments, working with collaborators, collecting and analyzing data, presenting the work at conferences and ultimately helping in writing a research publication will all serve as excellent experiences for the students. My research group currently is made up of three PhD students, and several undergraduate students. In addition, the research group shares the physical lab space with four other research groups, all of which conduct research in human-computer interaction. Therefore, there would be opportunities to meet other undergraduate and graduate students in the area of human-computer interaction. The students will be provided with a workspace in the lab.

Prerequisites: None.

COMPUTER SCIENCE

Data Driven Material Science Approaches

Advisor: Rodica Neamtu, rneamtu@wpi.edu

One-sentence description: Using machine learning to separate and analyze particle data to accurately predict flowability values for particles

Project description: This project aims to utilize computational approaches and machine learning models to predict the flowability of metal powders used in cold spray. This machine-learning-driven flowability research project has already opened the door to the use of new computational artificial intelligent methods in Additive Manufacturing that can have novel applications. For example, DDMS's models can predict the best mixture of powders that can be used to fix the gearbox of a helicopter, without having to take it offline for weeks and months for repair. Our cutting-edge techniques and tools could bring new insights into the analysis of cold spray process and enable researchers to perform unique comparative studies using a new particle analyzer machine called the REVOLUTION Powder Analyzer (by Mercury Scientific).

Skills the student will learn: Taking part in this project will give the student skills and more experience in the machine learning process from start to finish. These skills would include interpreting raw data, analyzing what is important, and building models to properly visualize and use the data. This project will teach the student to replicate processes performed by others and modifying them for their own applications. Lastly, this project will give the student skills of performing research and formally writing up the results.

Mentoring plan for the student: Stephen has already been connecting with my research group. Without being paid or getting credits, he joined our research meetings during most of C term and tried to understand our interdisciplinary approach to additive manufacturing. It would be a tremendous opportunity for him to be able to work full time with two other members of the group over the summer and start implementing a comparative tool. I have been acting as a mentor and advisor for many students for many years. I always work hard to get to know them and understand their goals and passions. I encourage my students to talk to me about anything, including academic, research, career advice, and mentoring. I meet with my students weekly to discuss their research and address their questions and challenges. I also organize a weekly meeting where my students share their work and actively try to help each other with constructive feedback and ideas. By interleaving supervised research, independent work, weekly one-on-one meetings, and weekly extended team meetings, the students will become an integral part of my research group and will get a better understanding of research and their interest in pursuing it. Their experience will involve conductive background research, understanding existing tools and methods, developing new tools and communicating about their work both verbally and in writing.

Prerequisites: None.

COMPUTER SCIENCE

Brain Data Exploratory and Analytics Tools

Advisor: Rodica Neamtu, rneamtu@wpi.edu

One-sentence description: This is an interdisciplinary project aiming to interleave computer science, data science and neuroscience to create and expand exploratory and discovery tools for brain data

Project description: I am looking for motivated students to work on expanding and extending an existing complex pipeline for analyzing and learning from brain data. This project would provide opportunities for students interested in developing and implementing tools for machine learning, data science, feature selection, signal processing, and information visualization. Our tools have been customized to work with brain data and help researchers get insights into big collections of fNIRs signals that otherwise would be missed.

Skills the student will learn: Key learning objectives include gaining an understanding of interdisciplinary brain data research, experience developing robust software platforms, and exposure to machine learning and data analytics. The goals of our project are two-fold: (1) Depending on student background and interest, the project may involve investigating tools for fNIRS exploration using Python, Matlab, D3, Javascript, etc, to enhance our existing data discovery and visualization pipeline. (2) In order to understand the interdisciplinary context, the students will engage in literature review, backend and user interface design and extension to incorporate machine learning tools.

Mentoring plan for the student: I have been acting as a mentor and advisor for many students for many years. I always work hard to get to know them and understand their goals and passions. I encourage my students to talk to me about anything, including academic, research, career advice, and mentoring. I meet with my students weekly to discuss their research and address their questions and challenges. I also organize a weekly meeting where my students share their work and actively try to help each other with constructive feedback and ideas. By interleaving supervised research, independent work, weekly one-on-one and extended team meetings, the students will become an integral part of my research group and will get a better understanding of research and their interest in pursuing it. Their experience will involve conducting background research, understanding existing tools and methods, developing new tools and communicating about their work both verbally and in writing. My research group currently has one PhD student, and several Masters and undergraduate students. In addition, my interdisciplinary research interests bring up opportunities to meet other undergraduate and graduate students in the area of data mining, machine learning and human computer interaction.

Prerequisites: None.

DATA SCIENCE

VisNLP 2.0: A Visual-Based Educational Support Platform for Learning Neural Network-Based NLP Analytics

Advisor: Chun-Kit Ngan, cngan@wpi.edu

One-sentence description: We develop and implement a Visual-Based Educational Support Platform that enables novice learners to study the core processing components of Neural Network-Based NLP Analytics in sequence.

Project description: In the Big Data era, there is a large amount of text information available on the Internet. To manage and process text information, Natural Language Processing (NLP) is the critical AI technology that can understand, analyze, and generate text without requiring a human lift a finger. However, to master NLP processes and techniques to develop such applications is not a trivial task, particularly at an introductory level, as it requires novice learners to have a good understanding of linguistic and computation that NLP is based on. Presently, there are two broad approaches for the NLP analytical processes: statistical-based (SL) and neural network-based (NN). The former approach is to perform statistical techniques to process and analyze text data. The latter approach is to use deep neural networks to conduct text mining and analytics. For the former approach, we have developed and implemented VisNLP 1.0 for learning Statistical NLP analytics. VisNLP 1.0 is a web-based, interactive visual learning platform that enables learners to study the core processing components of statistical NLP analytics in sequence. This work (https://www.scitepress.org/Papers/2021/103182/103182.pdf) has been accepted by the IVAPP 2021 conference. However, one critical problem that we have not addressed on is how the NN-based methods could be developed and implemented visually to deliver the knowledge to learners and to be contrasted with the SL-based approaches. To address this problem, we will proceed to develop and implement VisNLP 2.0 that is the advancement of VisNLP 1.0. Specifically, the team in this project will focus on the development and implementation of Word2Vec (CBOW and Skip-gram) that is one of the popular algorithms in the NN-based approaches. Using the interactive visual diagrams and charts being developed, we will visualize this approach to help learners understand the concepts, workflows, and uniqueness, as well as compare their performance with the SL-based methodologies.

Skills the student will learn: (1)Learn how to develop a NLP pipeline for Text Pre-processing. (2)Learn how to visualize NN-based NLP Analytics, i.e., Word2Vec (CBOW and Skip-gram). (3)Learn how to implement various performance metrics on text examples to demonstrate the difference between NN-based and SL-based methods.

Mentoring plan for the student: (1)1.5 Week: Assign the relevant papers and materials to students to read and ask them to present their readings and findings. (2) 7 Weeks: Discuss the development and implementation tasks with students and ask them to present their work progress. (3) 1.5 Week: Wrap up the project and ask students to prepare the final project deliverables and presentation.

Prerequisites: Any course work and project experience related to python, deep learning, NLP analytics pipeline, text mining, data visualization, D3.js JavaScript library, etc.

FIRE PROTECTION ENGINEERING & MECHANICAL ENGINEERING

Cooperative Spot Ignition of Structural Components by Multiple Heat Sources

Advisor: James L Urban, Jurban@wpi.edu

One-sentence description: Through experiments, this project examines the critical conditions for firebrand spotting, the ignition mechanism by which most structures (i.e., homes) are ignited during large wildland urban interface fires.

Project description: This project seeks to understand the physical mechanism (firebrand spotting) by which most structures (i.e. homes) are ignited in wildland urban interface fires such as the camp fire of Paradise, CA in 2018. Firebrand spotting occurs when burning debris (i.e., burning pieces of bark, or small pieces of burned wood) are lofted by the wind or fire induced flow. These small firebrands typically cannot ignite larger wooden components of structures such as wooden decks or siding by themselves, however they can accumulate into large groups that can readily ignite these fuels. The project will conduct experiments to determine how close the firebrands must be in order to act as an accumulation, as opposed to effectively acting alone. Based on numerical simulations conducted by Luke Zhu (PhD Student mentor) and Prof. Urban (Faculty Mentor) there should be a critical separation distance of roughly 5mm beyond which the firebrands act alone, and below which they cooperatively ignite the fuel. Based on the results of this computational modelling, the ignition conditions of wooden components by firebrands can be divided into several representative regimes that can help better explain how the firebrand accumulations cause ignite structures. These experiments will use resistance heaters controlled by a power supply to simulate the heating from firebrands while allowing fine control of the heating rate. The location of the heaters will be articulated on an adjustable track which will allow the separation distance between the heaters to be controlled. The time until ignition will be measured, and the impact of the separation distance determined. Different size heaters will be tested to examine the impact of the firebrand size.

Skills the student will learn: The student will gain technical research skills, communication skills, and skills of leveraging the other skills they learn toward furthering their career. The technical skills the student will develop will include "hands on" skills of setting up and conducting the experiments and post-processing of experimental data. Specifically, the student will work with the PhD student mentor to conduct experiments, repair the experimental rig as need, as well as post-processing and presenting the data. During the project, the student will work in the context of a collaborative and supportive research group. The mentors will learn communication skills of working in a laboratory group (i.e., data management, standard operating procedures, etc.). The student will also learn skills of more formal scientific communication in the form of preparing and giving a research presentation. The mentors will work with the student in preparing for the presentation while also showing the student presentations in lab meetings and seminars as examples. Finally, the student will gain professional development skills through guidance on how to leverage their summer research experience for future activities. The mentors will also explain to the student how to pursue a research career in the fields of Fire Protection or Mechanical Engineering if they are interested. This will include how to apply to graduate school, how to get accepted/funded and what to consider when choosing a program (MS/PhD, choosing an advisor, etc.). This will provide the student with skills to navigate the graduate school admissions process which can be a barrier to entry for students unfamiliar with it.

Mentoring plan for the student: The student will be directly mentored by the graduate student mentor (Luke Zhu) on a daily basis and by Professor Urban through a weekly individual meeting and during weekly research group meetings. The graduate student mentor will help the student overcome challenges or obstacles that occur during the project and provide day to day direction for the research project. The mentorship will also be facilitated through the collaborative department in the fire labs, where the student can reach out to other graduate students in the lab as well as the technical staff for advice on certain aspects of the project or general questions about the lab space. The mentors will ensure the student feels welcomed into the lab space, including make a point of introducing the student to the lab director (Ray Ranellone) and lab manager (Fredrick Brokaw), as well as the other researchers and faculty in the lab.

Prerequisites: Introductory Physics and Chemistry.

HUMANITIES & ARTS

Robots, AI, and the Future of Work

Advisor: Yunus Telliel, ydtelliel@wpi.edu

One-sentence description: This project will build a digital tool to help researchers understand and analyze potential workforce implications of the technologies they are building (e.g., the impact of AI and other automated systems on unemployment, job creation, worker reskilling).

Project description: The project aims to build a digital 'scenario planning' tool that supports researchers who seeks to combine technology innovation and workforce development. This tool will help researchers generate forecasts based on scenarios related to the workforce implications of technologies such as AI and other autonomous systems (e.g., job losses, need for workers' reskilling, creation of new jobs). The goal of scenario planning is not to predict what will happen, but to prepare researchers for future challenges. With this tool, researchers will be able to explore alternative futures, and become aware of uncertainties and limits, and align research design with an inclusive and equitable vision of workforce development. Such a dynamic perspective is vital. The public conversation on the future of work is often polarized between optimists and pessimists, and both of these camps tend to narrowly think about the number of jobs created or made obsolete. While this calculus is important, the relationship between technology and workforce development is more complex. The quality, security, and meaning of work in new technology environments is equally important. Furthermore, some newly-introduced technologies have the potential to make low-wage workforce invisible (e.g., digital content moderation industry). This picture gets more complicated when we consider gender, ethnic, and racial composition of the workforce. In response to this complex picture, scenario planning has the potential to consider multiple driving forces and uncertainties from a holistic perspective. Researchers fluent in scenario planning will thus have skills to navigate changing ecosystems of work and technology. This research has three components: 1) interviews with researchers funded by NSF's 'Future of Work at the Human-Technology Frontier' program, 2) construction of sample scenario analyses based on these interviews, and 3) building a digital tool that provides scenario planning prompts and guidelines. Students can participate in any or all of these components.

Skills the student will learn: Research methods used in social sciences: (1) Developing an understanding of scenario planning and other forecasting tools. (2) Library research. (3) Preparing a literature review (focusing on new technologies and the future of work). (4) Qualitative research design and data management. (5) IRB process and ethical considerations in research with humans. (6) Analysis of NSF grant writing . (7) Interviews (recorded and unrecorded; structured and unstructured). (8) Conceptual mapping (based on the terms, ideas and values that emerge from the interviews). (9) Information/communication design (in digital tool).

Mentoring plan for the student: This is part of an ongoing research project at WPI's Applied Robot Ethics Lab and NSF NRT Research Traineeship Program on 'Robots in the Future of Work'. Kathy Chen (STEM Ed Ctr Director) and an IMGD graduate student will also join at a later stage (i.e., building of digital scenario planning tool). Joining us in this project, the student will be able to closely observe how an anthropologist (who is trained in humanistic and social scientific methods) think about research design and methods. Week 1, 2, and 3: We'll read about and compare various scenario planning (and other forecasting) tools. The student will read my draft articles on the topic. We'll 'reverse engineer' some scenario planning analyses (e.g., how they reach these conclusions from an initial set of questions and assumptions). A librarian will train the student on various ways of using library resources. The student will prepare an annotated bibliography. I'll introduce the student to interviewing as a research method. Week 3, 4, 5, 6, and 7: The student will join me in most interviews with PIs and co-PIs of NSF's 'Future of Work at the Human-Technology Frontier' grants. I'll introduce the student to transcription software. We'll do transcriptions. We'll construct sample scenario analyses that focus on workforce development. Week 8, 9, and 10: An IMGD grad student will join us to help us with the design of the digital scenario planning tool. (optional for EREE student): If the EREE student has interest, they can participate in the design of a digital tool that creates scenario planning prompts. We'll work on a practical guide that shows how to incorporate insights from scenario planning into research design and NSF grant proposals

Prerequisites: None.

INTEGRATED & GLOBAL STUDIES

Open educational resources (OERs), curricula, and support services through public interest technology (PIT) for refugee education continuity

Advisor: Sarah Stanlick, sstanlick@wpi.edu

One-sentence description: This project is focused on exploring the potential for public interest technology and open educational resources to support, deepen, and/or deliver education of refugees across ages and stages.

Project description: At their ideal, schools can be safe havens, centers of educational growth, and provider of support services for the development and thriving of young people. The pandemic has challenged that role. Remote learning, thoughtful use of technology, and attention to social-emotional learning and support services for students have provided some bright spots and opportunities. Yet, inconsistency, readiness, social determinants, and issues of equity complicate that picture. For children escaping political persecution and resettling in new countries, this precarity is even more deeply felt. In recent years, the state of education in refugee camps and for resettled refugee children has garnered more attention, but lacks the resources and research needed to fully realize consistent, supportive, flexible educational resources. Much is still to be done and calls for urgent attention to this issue comes from organizations such as UNHCR, the International Rescue Committee, and other international relief organizations. Building off of work done at WPI on open educational resources, as well as my experience in refugee resettlement over the last decade, I will work with my student teams to explore the potential for technology, pedagogy, and professional development (via a train-the-trainer model) could be leveraged to bridge that education gap. Our goal would be to explore, study, recommend, and potentially start creating/co-creating resources that could be portable curriculum units, using an open-source, freely available learning management system. We would work with existing refugee resettlement partners and stakeholders to ensure an appropriate, practicable, and accessible design and implementation. Research questions include: 1. What lessons from the shift to remote learning can be applied to refugee education? 2. What opportunities exist to leverage technology and open educational resources to support refugee education? 3. Which levels/age groups should be the focus of this learning/training and how might we support ongoing learning through PIT and OERs?

Skills the student will learn: This would be a project that would be well-served by students interested in ethics, technology, education, global studies, and social justice. Students will gain a conceptual understanding of public interest technology, open educational resources, and the challenges/opportunities for refugee resettlement. They will also learn about community-engaged research methods and ethical social science research. This includes, but is not limited to, assetbased community engagement and a systems-level view of social problems and their root causes. The students will also develop team building, surveying, presentation, public speaking, and team management skills.

Mentoring plan for the student: I will be creating a small start-up list of readings and resources to prepare the students for the experience and ground them in existing research and theory as it pertains to the topic. The team will be meeting frequently, and student(s) will also have a role in planning and facilitating research meetings. The students will have weekly skills development workshops that will address public speaking, team communication, science communication, ethics, community-engaged research, and social science methodology. In addition, the goal will be working towards a paper or other deliverable that will add to the larger understanding of technology's ability to support or transform refugee education. As such, the students will be working on short deliverables throughout the summer (including infographics, presentations, an annotated bibliography, etc.) that will all be working towards that larger deliverable. As we do not have graduate students in DIGS (yet), I am assuming responsibility for the mentoring for this project. I would welcome a graduate student from learning sciences, psychology, or computer science that could also serve as a co-mentor to help with pedagogical literature and develop their mentoring skills to work with undergraduates. I would be using the book "Team Writing" to help the students come up with a charter and a plan for operationalizing team responsibilities. I will also hold periodic individual check-ins to ensure students feel supported and that they are developing in line with personal academic goals. As a first-generation college student, I know how important strong mentoring is to developing scholarly identity.

Prerequisites: None.

MATERIALS SCIENCE & ENGINEERING

3D Printing Food for Novel Patient-Based Applications

Advisor: Danielle Cote, dlcote2@wpi.edu

One-sentence description: This project will use materials science coupled with novel 3D Food Printing techniques to develop food products with customized nutritional content.

Project description: 3D printing (additive manufacturing) has recently exploded in popularity in applications ranging from metallic aerospace and automotive components to polymer prototyping. This project uses 3D printing for a novel application – food production. While initially this technology was purely esthetic and fun, there is new research suggesting it can be used to aid in recovery from medical ailments. For instance, in post-acute care, traumatic brain injury patients often must regain the ability to eat (chew and swallow) before they can regain speech. Additionally, in geriatric care settings, ensuring adequate calorie intake for patients is crucial for prolonging organ function and reducing mortality risk. However, the nature of most typical food products does not allow for a precision approach to designing meals. As ongoing work in my laboratory, researchers are investigating how to create 3D printed food products that are matched to an individual's bite force ability and texture needs for swallowing. Additionally, 3D printed food can allow completely individualized and customized nutrition-contents in food products for consumers based on their nutritional needs. For instance, patients with a vitamin D deficiency will have their food product printed at the time of the deficiency supplemented with vitamin D, as well as a desired quantity of calories to meet other health metrics. The applications described here require "feedstock" (input material) food that meet both nutritional and material property criteria. The project will combine these requirements into a focused effort to identify and create feedstock food products to be used in the application projects described. This project will focus on the materials science and nutritional properties of the feedstock foods and will be integrated into the larger application projects described above. Skills the student will learn: The student will gain both technical and professional skills while participating in this research project. The student will work closely with the graduate student advisee, myself, as well as the rest of the research team, currently consisting of a research professor, a postdoctoral scholar, five PhD students, and several master and undergraduate students from various disciplines. The student will participate in my research team's weekly update meetings, sharing their current research progress and learning about the other research group efforts. Additionally, they will engage in summer outreach activities with the group (TouchTomorrow, for example), join meetings with external industry and government collaborators, and participate in other day-to-day activities that the group performs (e.g. instrument maintenance or trainings, lab clean-ups, chemical inventory events, etc.). This gives the student excellent first-hand exposure to research in a university setting as well as insight into the professional research realm. Technically, the student will have exposure to a novel 3D food printer, as well as extensive advanced materials science characterization equipment, including light and electron microscopes, powder and fluid rheometers, differential scanning calorimetry, nano and microhardness instruments, mechanical property testers, and more. These types of characterization techniques are very useful skills to have and can be applied to materials in a wide range of applications, giving the student a broad characterization background. Additionally, the student will present their research at weekly group meetings as well as potential external meetings. Depending on the progress, the student will be encouraged to co-author one of the peer-reviewed journal articles planned on their work as well.

Mentoring plan for the student: Every summer for the past five years my research group has hosted high school and undergraduate students. Having this experience has allowed us to build an "onboarding portfolio" of materials used to bring students into our group. These materials include introductory presentations given by current students, suggested background reading and viewing material, and a formal shadowing schedule where the new student shadows each group member to experience all of instruments in the lab that may be relevant to their research. After this onboarding, the student will join our weekly group meetings. Additionally, they will meet one-on-one with the graduate student advisee daily to review specific tasks and needs, and for general check-ins. The graduate student advisee will also serve as the student's first point of contact and will be available to the student for any questions. Third-year Ph.D. student, Jack Grubbs, will lead the student's mentoring plan. Jack has two years of experience mentoring undergraduate students in our research lab, and three years mentoring high school students. Jack has a career goal of being a materials science professor and enjoys the student interactions as well as the mentoring experience. Additionally, my postdoctoral student, Kyle Tsaknopoulos, serves as Jack's mentee in our group. She will indirectly be monitoring the relationship between Jack and the student. Finally, I am in close contact with both Jack and Kyle and will oversee the student's overall progress.

Prerequisites: ES2001 Introduction to Materials Science

MECHANICAL ENGINEERING

Design of a Novel Colonoscopy Probe

Advisor: Ahmet Can Sabuncu, csabuncu@gmail.com

One-sentence description: This is a mechanical and electrical engineering design project to develop a continuum robot with embedded sensors for measuring electrical impedance in a medical device probe that will help doctors characterize tumors and make diagnostic decisions.

Project description: In this project, we develop an endoscopy tool to characterize lesions on gastrointestinal tract. The tool uses electrical impedance measurements to characterize tumors. Our hope is to quickly analyze tumors during colonoscopy to guide biopsy decisions.

Skills the student will learn: Skills to produce minimal viable products. Skills to test prototypes for specific objectives. Skills to evaluate testing results.

Mentoring plan for the student: Our team currently has 1 post doc, 1 MS student and 3 undergraduate students. The student will be integrated into the design and evaluation team and will join the weekly meetings. The lab work will be supervised by Erik Skorina, our post doc.

Prerequisites: Practical “maker skills”.

MECHANICAL ENGINEERING

Clean Rare Earth Metal Production and Recycling

Advisor: Adam Powell, acpowell@wpi.edu

One-sentence description: A rare earth metal industry study, and modeling and experimentation, will investigate multiple methods for reducing pollution in the rare earth metal industry, to clean up a heavily-polluting supply chain for critical materials in clean energy technology.

Project description: Rare earth permanent magnets are in every hybrid, electric, and hydrogen vehicle, as well as every offshore wind turbine - leading the clean energy revolution. And yet, rare earth metal production (Nd, Pr, Dy) is horrendously dirty, involving water pollution in separations, and perfluorocarbon emissions (GWP 6000+) in oxide reduction to metal. This project is examining new methods for rare earth metal production and recycling to meet clean energy needs. Extraction from aluminum and phosphate mining wastes can reduce or eliminate emissions from rare earth mines. A new semi-continuous calciothermal rare earth oxide reduction process eliminates perfluorocarbon emissions. And a new efficient magnet recycling process based on liquid magnesium leaching and efficient multiple effect distillation can create a circular economy in rare earths. This summer, the Energy Metals Research Group will complete a broad industry study to identify the technical and economic feasibility of these new technologies for dramatically reducing emissions across the value chain. We will work with multiple companies to gather data and identify best modes of cooperation. And we will begin cost-effective reduction of risk toward deployment of these technologies.

Skills the student will learn: The student will gain skills in techno-economic analysis of materials processes, and others driven by project needs and student aptitudes/interests. In particular, thermodynamic modeling, and finite element analysis of fluid dynamics and heat and mass transfer, will likely be components of the project. And the student will participate in experimental work on at least one of the technologies described above.

Mentoring plan for the student: The student will work most closely with Chinenye Chinwego, a PhD student in the group and experienced entrepreneur. Group leader and PI Adam Powell will meet with the team weekly to review progress, discuss next steps, and set up industry meetings. At least four meetings during the summer will discuss the student's interests, aptitudes and career goals, and assess how the project can advance those goals.

Prerequisites: There are many helpful skills and background experiences, such as GPS to programming, design, thermo, fluids, heat and mass transfer, but no firm prerequisites.

MECHANICAL ENGINEERING

Cardiovascular Medical Simulation

Advisor: Yihao Zheng, yzheng8@wpi.edu

One-sentence description: 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.

Skills the student will learn: Medical simulation; Tissue mimicking materials; Human cardiovascular anatomy and physiology; Testing of interventional devices; Background knowledge in interventional surgery; Software to process patient medical image data; Literature review; Computer aided design and manufacturing; Additive manufacturing;

Mentoring plan for the student: I will serve as the student's mentor. Weekly group meetings will give the student opportunities to learn multiple other projects in medical and manufacturing innovation. Individual research meetings can be scheduled as needed.

Prerequisites: None.

PHYSICS

Mixing dynamics of active fluid in a cavity flow system

Advisor: Kun-Ta Wu, kwu@wpi.edu

One-sentence description: This project seeks to improve the mixing dynamics in a container using novel active fluids to improve mixing efficiency for micro-mixing technologies.

Project description: Mixing is ubiquitous from baking a birthday cake at home to synthesizing materials in industries. The essence of mixing involves repeated processes of stretching and folding. To stretch and fold fluids not only requires external energy input but also self-reorientation of fluid flows. For example, in the conventional cavity flow system, fluids are confined in a cuboid chamber with one surface moving at a constant velocity. Studies have shown that the fluids in this system are driven to mix, but the mixing efficiency decays as 1/t because the fluid flows lack self-reorientation and reached a steady state, which inhibits the mixing process. To overcome this limit, we will adopt active fluid to reorient flows. Active fluid is differentiated from conventional passive fluid such as water by its capability of self-pumping without the need of external pumps. Equipped with this capability, active fluids have been shown to perform the task beyond the limit of passive fluid such as self-transporting cargos from Point A to Point B. Thus, we hypothesize that adopting active fluid to the cavity flow system will not only overcome the constraint of the 1/t decay but also boost the mixing efficiency of the cavity flow system. To test the hypothesis, we will measure the mixing efficiency, the specific rates of stretching and circulation order parameter of active fluid while systematically varying the fluid activity level (self-flowing speed). Then we will plot these measured quantities as a function of self-flowing speed in a log-log axis and fit the data to a line. If the slope of the fit line is positive, the hypothesis is verified. This project will be the first experiment to demonstrate how active fluid can overcome the limit in traditional mixing dynamics.

Skills the student will learn: Basic wet lab skills such as pipetting and titration. Coat the glass surface with polymers. Protein purification. Polymerize microtubules. Synthesize kinesin-driven, microtubule-based active fluids. PID algorithm for machine automation such as temperature control. Fluorescent microscopy. Traditional cavity flow. CNC machining. 3D printing. Arduino control. Data analysis with Matlab, including using the algorithms of particle tracking and particle image velocimetry. Parallel computation on Turing clusters. Keep a lab notebook. Oral presentation with PowerPoint. Compose posters with Adobe Illustrator

Mentoring plan for the student: The student will be paired with one of my graduate students, Teagan Bate to learn basic research skills such as pipetting and data analysis and one of my undergraduate students, Yen-Chen Chen to learn about mechanical engineering skills such as CNC machining. The student will also join our weekly group meeting to learn how the scientific research is discussed and progressed. To enhance the student's awareness of the research outside WPI, the student will be encouraged to join New England Complex Fluid Workshop at MIT in June, which will also broaden the student's connection to nearby scientists in the similar field. Additionally, my lab is closely connected with NSF MRSEC at Brandeis University in Waltham. I will arrange the student to participate in the meeting of Interdisciplinary Research Group (IRG). I envision such an activity will provide the student a unique opportunity to engage with the MRSEC director, as well as pave the path to student's career development in the long run.

Prerequisites: No specific courses, but a passion toward the fundamental science is a prerequisite.

PHYSICS

Photoconductivity of a 2D solar energy conversion materials

Advisor: Lyubov Titova, ltitova@wpi.edu

One-sentence description: This project will use terahertz (THz) spectroscopy to study photoconductivity in a novel 2D material with applications in photodetectors, solar cells and photocatalys.

Project description: Two-dimensional (2D) layered materials are attracting attention of scientific and engineering community as candidate for flexible, inexpensive and efficient optoelectronic and photovoltaic devices. In these materials, atomic layers characterized by strong in-plane covalent bonds are held together via weak van der Waals forces. It is possible to isolate single- and few-layer sheets of 2D materials with lateral dimensions as large as few millimeters similar using the same approach (exfoliation) that allowed Novoselov and Geim to obtain graphene, the first discovered 2D material. In this project, a student will study light-induced conductivity in 2D bismuth oxyiodide (BiOI). This material efficiently absorbs light in the blue-green part of the visible spectrum, making it attractive to many applications such as photodetectors, solar cells and photocatalysts. They will use time-resolved THz spectroscopy (TRTS) to study processes that take place in thin BiOI layers after it has been excited by a light pulse. Analysis of THz pulses transmitted through a material with and without optical excitation allow tracking the changes in material properties after excitation with an ultrashort optical pulse. Specifically, TRTS allows monitoring the time-evolution of light-induced conductivity without the need for electrical contacts.

Skills the student will learn: Laser operation, optical alignment, optical properties of solar materials, data analysis and presentation.

Mentoring plan for the student: Student will join a vibrant group of three graduate students and three undergraduate researchers, including two REU students. They will participate in all the same professional development seminars and workshops as REU students. PhD student who will mentor the student is an experienced mentor, she has completed a mentoring workshop taught by Dr. Kathy Chen, and has been awarded an Outstanding Mentor Award by the Physics Department.

Prerequisites: PH1130 Modern Physics.

PHYSICS

Investigation of astrophysical phenomena through the ALMA data

Advisor: Rudra Kafle, rpk101@wpi.edu

One-sentence description: We will be studying some astrophysical phenomena through the publicly available data from the ALMA radio telescope.

Project description: Project description: The Atacama Large Millimeter/submillimeter Array (ALMA) Science Archive (ASA) contains huge amount of data obtained from the sky survey. ALMA is currently producing roughly 500TB worth of raw-data and reduced data products per year. A large amount of the public data can be accessed anonymously from the following archive page: https://almascience.nrao.edu/asax/. Prof. Doug Petkie and I advised a group of physics students who are completing their MQP working on these data and investigating various astrophysical phenomena like interstellar dust from the supernova explosions, signatures of life in Venus, study of high redshift quasars, etc. Through these projects, students have gained various computational and data analysis skills in addition to the exploration of the astrophysical phenomena. I, in collaboration with Prof. Petkie, would like to engage junior and senior students in the study of astrophysical phenomena through the analysis of the ALMA data.

Skills the student will learn: After the completion of this project, students will be able to download publicly available astrophysical data and analyze them. This will give them an exposure to research techniques/methodologies so that they will prepare themselves for their MQP research, and graduate studies in the field of observational/computational/theoretical astrophysics.

Mentoring plan for the student: Prof. Petkie and I will jointly advise the students in the project.

Prerequisites: PH2540 Solar Systems.

PHYSICS

Terahertz Spectroscopy of Astrophysical Molecules

Advisor: Doug Petkie, dtpetkie@wpi.edu

One-sentence description: Gas phase molecular spectroscopy for laboratory experiments and astrophysical observations

Project description: Terahertz radiation interacts with the quantized rotational energy levels of gas phase molecules that result in spectral fingerprints that identify and quantify molecules for many applications, from breath analysis and environmental sensing to astrophysics. Laboratory spectroscopy plays a foundational role in recording and modeling the spectra with quantum mechanical Hamiltonians that are used to predict the complex spectra for these scientific applications. The project as two synergistic components, one is to begin construction a laboratory spectrometer and the other is to use the Atacama Large Millimeter/submillimeter Array (ALMA) Science Portal to analyze astronomical data. The laboratory spectrometer has several components to consider, such as the source, detector, absorption cell, optical components, gas handling, vacuum system, signal conditioning, computer control, data acquisition and signal processing. The ALMA data will be analyzed with the Cube Analysis and Rendering Tool for Astronomy (CARTA) as well as other software packages and will involve identifying objects to study, such as the interstellar medium, star forming regions, and planets. While students will be involved in each component of the project, a student can spend majority of time on one project based on interests.

Skills the student will learn: Skills gained will be in three main areas. The first are scientific skills of doing research that will include literature reviews to identify areas of scientific need and to determine the feasibility of the research project. Coupled to this is to learn the fundamental physics and engineering principles associated with the projects that include interaction of electromagnetic radiation with matter, quantum mechanical descriptions of molecules related to atomic and molecular spectroscopy, and astrophysical models of objects in the universe. Experimental skills are another main area that were described in the proposed project that involve the development of instrumentation and data acquisition to construct and entire spectrometer. This will include design consideration to optimize the spectrometer for gas phase molecular spectroscopy at low pressures. Like the construction of the laboratory spectrometer, students will study the design and instrumentation of the ALMA telescope in connection with past and future astronomical observations to be able to interpret the resulting observational data. Computational skills are the last main area that includes data collection and instrument control, signal/data processing, and scientifically modeling the data. These three skill sets support the scientific investigations we will be engaged in.

Mentoring plan for the student: There is a network of students at different levels that are part of my group that include PhD students and other undergraduate students. I pair new students with experienced students for mentoring and we have weekly group meeting. I also have induvial meetings with students at least once a week and have an automatic appointment system via Bookings and Zoom that has worked really well when students need input from me.

Prerequisites: None.

ROBOTICS ENGINEERING

Convertible CAAR (Concentric Agonist-Antagonist Robot)

Advisor: Loris Fichera, lfichera@wpi.edu

One-sentence description: The goal of this project is to design a new type of flexible robot for surgical procedures.

Project description: The goal of this project is to create a new flexible continuum robot for use in robotic grippers, surgical robots, etc. The design will be based on the CAAR concept (see SCREAM 2.0 MQP), which we will modify to make it reconfigurable (convertible) during operation. This new robot will feature larger accessible workspace and dexterity than traditional CAARs. The project will involve mechanical design, prototyping (mostly 3D printing), and kinematic characterization. Results of this study are expected to be disseminated in a peer-reviewed conference article.

Skills the student will learn: Throughout the EREE period, I expect the student to grow in the following areas: *Technical skills:* * Kinematics of continuum robots. *Research skills:* * Critical thinking * Reading and evaluating prior literature * Presenting academic research * Research ethics and academic integrity.

Mentoring plan for the student: My mentoring approach involves making a work plan early on, defining milestones and deadlines. Project timelines are invaluable tools both for students and for mentors, as they help students stay on top of their tasks, and help mentors keep track of their students' progress. I take the time to discuss with my students about their interests and career objectives and use this information to help them set up "strategic" goals. For students interested in research, these goals typically include the development of core research skills such as performing a literature review, designing an experiment, analyzing experimental data and writing a scientific manuscript. Three of the undergraduate projects I have advised in recent years have resulted in peer-reviewed conference papers. One of these papers was finalist for best paper award (DMD 2019), while another one recently won the best student paper award (SPIE Medical Imaging 2021). Whenever possible, I try to pair undergraduate students with graduate students on the same project: for an undergraduate student, working with a senior colleague is an invaluable experience as they get to learn important technical and soft skills. For graduate students, having a direct relationship with a junior colleague becomes an opportunity to develop mentoring skills, which may one day become very valuable - especially if they decide to pursue an academic career. For this EREE project, the undergraduate student will work side to side with one of my PhD students, Alex Chiluisa. I will personally work on this project myself throughout the summer, and therefore both Alex and the student will have access to me all the time. I believe that the mentor-mentee relationship does not resolve with the end of research experience - as a matter of fact, I continue to cultivate a good relationship with all of the individuals who have mentored me in the past. I wish to pass this forward to my own mentees.

Prerequisites: RBE 2002 Unified Robotics II or above.

SYSTEMS ENGINEERING

Policy Modeling

Advisor: Shamsnaz V Bhada, ssvirani@wpi.edu

One-sentence description: Tracing policy to engineered system to establish consensus.

Project description: In this project student will work on using the natural language policy and convert it to a machine-readable entity.

Skills the student will learn: Coding, Modeling, visualization, game design

Mentoring plan for the student: The student will meet with the Faculty every week, we will work on developing a project plan early in the term and have a set of deliverables. The student can build a paper to be submitted to a conference on their experience in the project. The student will work with other members of the team to complete the project.

Prerequisites: CS1004 Introduction to Programming for Non-Majors or equivalent.