SIU SOUTHERN ILLINOIS UNIVERSITY CARBONDALE STEM EDUCATION RESEARCH CENTER

2024 High School Summer Researchers Project

Southern Illinois University

Coordinated by

The STEM Education Research Center

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Southern Illinois University (SIU) is excited to present an initial list of research projects open to high school students. The list of 17 projects in this document span a range of topics and timelines for participation. The STEM Education Research Center (SERC) at SIU will act as the point of contact and our staff will coordinate the process.

In addition to the 17 projects, we offer our services to match students with SIU faculty and staff for other research ideas. Please contact Dr. Brown if you would like to explore other projects. SIU is a research institution that takes pride in our undergraduate research opportunities and now extends the invitation to high school students during our summer research program.

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Project Title: White Light Solar Flares

Start Date: Ongoing **End Date:** Ongoing

Project Description: During 2024, the Sun is very active, with many sunspots, prominences, and solar flares. This project is monitoring the Sun daily with a white light telescope to observe solar activity.

Work Student(s) will Complete: The student will learn to set up a telescope each day to image the sun. The student will also learn to input the data from the collected images into a computer program to search for solar flares.

Number of students Needed: One

Contact Information:
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Project Title: Rare Earth Minerals at the Hicks Dome Intrusion, Hardin Co, IL

Start Date: ~June 1 **End Date:** ~July 30

Project Description: Hicks Dome is a cryptovolcanic feature in Hardin County, IL consisting of igneous rock with highly unusual compositions, shatter breccias, and veins of hydrothermal mineralization. Among these minerals in some locations are Rare Earth ore minerals, which could potentially be an economic resource. However, samples collected from across the dome require X-ray diffraction analysis to search for occurrences of these minerals.

Work Student(s) will Complete: Students will work in my mineralogy lab to cut, powder, and prepare rock samples from Hicks Dome, and then analyze them using our X-ray diffraction instrument. Students will learn how to operate the instrument, collect data, and then analyze the data to find the mineral content of the samples. Any samples that show Rare Earth content will be further investigated.

Number of students Needed: 2

Contact Information:
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Project Title: Media Arts and the Sciences

Start Date: I could begin at any time, as early as Summer 2024 (May 15 onward) **End Date:** Indefinite

Project Description: One of my areas of research expertise is the relationship between the humanities (particularly theater, film and television) and the "sciences" (writ large: physics, chemistry, biology, engineering, mathematics). I was chair of the Department of Media and Theater Arts at Montana State University, wherein I taught science and nature studies courses in the MFA program in science and natural history filmmaking. I supervised a dozen or so MFA thesis projects. I have published four articles in science studies (on Carl Sagan's Cosmos, on the representation of the nature of human memory, an application of nuclear criticism to BBC/Discovery's "battlefield" series of nature films, and political economy critique of the Discovery cable network, which partially funded the MFA program at Montana State University.

Work Student(s) will Complete: I would teach high school students how to think critically about the nature of science and its sociological impact. Students would read science studies and PUST books (the public understanding of science and technology, such as Carl Sagan's The Demon-Haunted World and E.O. Wilson's Consilience, I would set the terms for learning to speak about and write criticism of plays (Michael Frayn's Copenhagen), films (Michel Gondry's Human Nature), and television (Carl Sagan's Cosmos).

Number of students Needed: Unlimited. 24 might be an ideal number: I could have students work in triangular groups of 3. However, my classes work best when the largest number of students assemble, in order to maximize the chance of transforming the thinking of as many students as possible.

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Project Title: Light Pollution in Southern Illinois

Start Date: Ongoing **End Date:** Ongoing

Project Description: Astronomy is best done in a truly dark environment. The spread of cities and habitation across the region has brought more and more man-made light that interferes with the view of the stars at night. Besides affecting astronomers, this light pollution has also been shown to have impacts on human sleep patterns, plant growth, and the behaviors of nocturnal animals. A survey of the light pollution for a given area can help city or campus planners identify and reduce the sources of the light pollution. In this case, a survey of light pollution on the Southern Illinois University Carbondale campus will be conducted, and the results will be mapped.

Work Student(s) will Complete: The student(s) would be taking nighttime light level readings across the SIU Carbondale campus at night. This is done w/a laptop computer and a simple handheld meter. They would then be inputting this data into a spreadsheet in order to create of light-level map for the area.

Number of students Needed: 1-2

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Project Title: Developing Deep Learning algorithms for Classifying the Growth Stages of Weeds in Soybean Field

Start Date: 09/01/2023 **End Date:** 08/31/2024

Project Description: The proposed project will utilize deep learning algorithms, drones and edge-cloud infrastructure for automated weed management in soybean fields to reduce herbicide usage. An accurate, automatic, low-cost, environment-friendly, and real-time weed detection technique is critical to improve agricultural productivity and profitability. While automating the weed classification process according to growth stages is crucial for such weed controlling techniques, unfortunately, current research and state-of-the-art automated solutions on detecting and classifying the growth stages of weeds in soybean fields are significantly lacking. Our proposed solution will detect and classify the growth stages of weeds in soybean fields to promote selective usage of herbicides.

Work Student(s) will Complete: Work with the graduate students to: 1. Label the collected frames with weeds growth stages 2. Clean the collected dataset. 3. Train a model on the collected dataset. 4. Test the model.

Number of students Needed: 2

Contact Information:
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Project Title: The U.S. Supreme Court losing legitimacy

Start Date: It grows out of last year's sabbatical **End Date:** next year hopefully

Project Description: I'm expanding on my GJR project on the Supreme Court's legitimacy to hopefully make it into a book

Work Student(s) will Complete: none

Number of students Needed: 0

Contact Information:
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Project Title: Computational-aided High-Spectroscopy Investigation of Cancer Biomarker p53

Start Date: 05/13/2024 **End Date:** 08/30/2024

Project Description: Epithelial ovarian cancer (EOC), the deadliest gynecologic cancer, is dubbed the "silent killer" due to subtle symptoms and a lack of reliable early screening. Abnormal cell signaling fuels EOC initiation, progression, and treatment resistance through pathways like Ras, P13K, p53, and TGF-β. Serous EOC has low-grade (linked to KRAS, NRAS, BRAF mutations) and high-grade (associated with TP53, BRCA mutations) subtypes. The TP53 gene produces the vital tumor suppressor p53, pivotal in tumor development. The roles of wildtype p53 (wt-p53) and mutant p53 (mut-p53) are unclear, with studies suggesting mut-p53's involvement in initiation or interference with wt-p53 functions. Studying mut-p53 alongside wt-p53 could unveil insights into cancer biology, necessitating ongoing p53 monitoring. Direct monitoring is challenging, requiring a non-invasive tool for simultaneous screening of mut-p53 and wt-p53. Our summer research will employ innovative methods—such as in-silico modeling, aptamer-based Raman label affinity purification, and data-driven experiments—to preliminarily explore mut-p53/wt-p53 roles and mutation types.

Work Student(s) will Complete: High school students will engage in a hands-on project where they'll explore the fascinating worlds of in silico modeling, Raman spectroscopy, biocconjugation, and Python data analysis. Through this project, students will learn how to use computational models to simulate biological processes (in silico), understand the principles of Raman spectroscopy for molecular analysis, explore the concept of biocconjugation to label and study biomolecules, and utilize Python for data analysis. This comprehensive learning experience aims to provide students with practical skills in computational biology, spectroscopy, biochemistry, and programming.

Number of students Needed: 2

Contact Information:
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Project Title: Explainability and Vulnerability Analysis of Large Language Models Through Reverse Engineering

Start Date: Feb 2024 **End Date:** Jan 2025

Project Description: Abstract: Large language models (LLMs) demonstrate impressive linguistic capabilities but suffer from issues like bias, toxicity, and adversarial vulnerabilities. This research aims to reverse engineer popular LLMs to audit their internals - architectures, attention mechanisms, embeddings - and analyze how their design choices relate to ethical risks. Both model extraction and adversarial testing will be used to evaluate LLMs from perspectives of robustness, fairness and transparency. The outcomes can inform the principled development of trustworthy language technologies. Motivation: The impressive capabilities of large language models (LLM) like GPT-3 are accompanied by transparency and ethical issues like bias. Their opaque internals preclude deep analyses into failure modes. Objectives This research aims to audit popular LLMs by: Extracting model dynamics like attention weights and embeddings. Generating adversarial examples to systematically induce and catalog failures. Quantifying model robustness to perturbations. Tracing links from model mechanics to flawed output behaviors. Approach Leverage model extraction, adversarial testing, causal analysis and behavioral rubrics to evaluate LLMs as “black boxes”. Reconstruct components for visibility into how architectural choices propagate issues. Outcomes The reverse engineering provides empirical insights into engineering vulnerabilities within LLM internals to inform improving reliability and align outcomes to ethical standards. Enhanced transparency will enable oversight into deficiencies. Impact Strengthen accountability into opaque but influential LLMs by revealing connections between infrastructure and negative impacts tractable to mitigation by designers. Inform governance for trustworthy AI.

Work Student(s) will Complete: This mix of technical tasks and higher-level investigations aims to provide students with exposure to cutting-edge AI auditing. . 1. Model Reconstruction Assist experimental work on querying commercial LLMs to clone model dynamics Profile attention mechanisms and track how perturbations shift attention distributions Evaluate alignment of extracted synthetic models to originals 2. Adversarial Testing Curate textual inputs to trigger model failure modes Analyze model-generated rationales during failures Quantify robustness metrics like epoch to instability 3. Output Analysis Annotate model responses for characteristics like toxicity Develop rubrics to categorize and document different failure types Correlate failure modes with model layers affected 4. Societal Analysis Catalog historical and social contexts behind biased analogies Document harms associated with model vulnerabilities Construct test cases reflecting ethical dilemmas

Number of students Needed: 2-3

Contact Information:
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Project Title: Middle Mississippi River wetlands: history, geology, and sustainability

Start Date: NA **End Date:** NA

Project Description: The research project deals with understanding the role of Middle Mississippi wetlands in processing excessive nitrogen pollutants. We use field and lab-based techniques to quantify hydrological and biogeochemical processes contributing to pollution reductions. The project includes historical and cultural perspectives of the fertile plains of the Middle Mississippi River and the people who have been living near the river.

Work Student(s) will Complete: The students will perform fieldwork at some of the wetlands in Southern Illinois where they will see and learn about the river, river processes, and wetlands. They will collect water samples from surface and groundwater and analyze them in the geochemistry laboratory at SIU. The project will have a second part in which the data will be analyzed and a report will be produced.

Number of students Needed: 5 - 12

Contact Information:
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Project Title: Intelligent Online Machine Learning for Data Streams in Open Feature Spaces

Start Date: 08/16/2023 **End Date:** 08/15/2026

Project Description: This project aims to investigate novel interpretable, adaptable, and scalable intelligent online machine learning for streaming analytics in open feature spaces, where new features can emerge constantly, and old features may vanish over time. The research objectives will give rise to a comprehensive mathematical and computational framework for intelligent online machine learning, through a deeper understanding of new research problems and objectives, novel sparse online models, innovative active learning algorithms, and robustness-aware techniques for non-stationary data streams in open environments.

Work Student(s) will Complete: (1) understand the online optimization problems and algorithms for big streaming data analysis; (2) understand existing sparse online learning for data streams in fixed feature spaces; (3) understand existing online active learning for data streams in fixed feature spaces; (4) investigate novel sparse online learning strategies for data streams in open feature spaces; (5) investigate innovative online active learning strategies for data streams in open feature spaces; (6) explore new sparse online learning and online active learning paradigms for data streams in open feature spaces.

Number of students Needed: 3-5

Contact Information:
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Project Title: Algae Unlocked

Start Date: 4/1 **End Date:** 11/1

Project Description: We are a student team that has applied to a DOE research challenge. We are preparing a proposal to explore dissolving microalgae into water as a biostimulant for a research crop of corn and hemp. we do not know if we have won until Jan 15th.

Work Student(s) will Complete: We will need help with agricultural field studies and tending to the plants, taking notes, conducting experiments.

Number of students Needed: 2-4

Contact Information:
Dr. Scott Hamilton-Brehm,
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Project Title: Bird Community Surveys with Autonomous Sound Recorders

Start Date: April 2024 **End Date:** August 2024

Project Description: The project is part of a long-term study of bird responses to forest management as part of a 100-year Hardwood Ecosystem Experiment (www.heeforeststudy.org), which takes place on two state forests near Bloomington, Indiana. My group uses sound (bioacoustics) to study bird communities.

Work Student(s) will Complete: Field work will include taking forest-based measurements, deploying acoustic recorders, and general tasks associated with the research. Students interested in natural resources - wildlife or forestry - should fit well for this position.

Number of students Needed: 2

Contact Information:
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Project Title: Southern Illinois White-Tailed Deer Fawn Study

Start Date: May 20th **End Date:** June 30th

Project Description: Each summer, a crew of grad students and technicians surveys areas around Carbondale to find white-tailed deer fawns and fit them with a little collar to track their survival.

Work Student(s) will Complete: The high school students could tag along the crew and assist in the work. The work is physically difficult. Long day hiking in tall vegetation in hot temperature with lots of ticks. But students would get to have hands-on experience with field biology.

Number of students Needed: I could accommodate around 2 students. They could stay the whole time or they could rotate.

Contact Information:
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Project Title: Assessing Best Management Practices for Minimizing Nitrogen Loss from Starter Fertilizers in Corn and Soybean Production

Start Date: Ongoing **End Date:** Ongoing

Project Description: Farmers often apply starter fertilizers to corn and soybean during the fallow period (after harvesting either corn or soybean until the next May). Many of these fertilizers have nitrogen as a component of the fertilizer and thus, susceptible to losses to air or water. Several practices such as using fertilizers with no N components or using inhibitors that suppress those N conversion to plant available are proposed to minimize N loss and therefore, utilize the N in these starter fertilizers. Currently, there is limited studies on evaluating these practices and quantifying the magnitude of N loss through nitrate-N leaching or nitrous oxide emissions. This project monitors these two N loss pathways to quantify how much starter fertilizers (during the fallow periods) contribute to overall N loss in Illinois.

Work Student(s) will Complete: The student will learn about fertilizers, cropping systems, measuring, analyzing, and calculating nitrate-N and nitrous oxide emissions in field and laboratory. The student will also be trained for presenting the results at scientific meetings as well as field days.

Number of students Needed: Two

Contact Information:
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Project Title: Assessing Agronomic Practices with Sulfur Fertilization in Soybean

Start Date: Ongoing **End Date:** Ongoing

Project Description: Since the passage of the Clean Air Act, deposition of sulfur has been reduced in agricultural farms. Recently, many farms in Illinois have shown signs of sulfur deficiency especially in soybean and corn. Sulfur is an essential plant nutrient that is important for maximum soybean production and thus, deficiency of sulfur can result in lower yields and loss of farm profit. Certain practices such as tillage can make sulfur more accessible for soybean. This study aims at assessing a combination of agronomic practices and sulfur fertilization to ensure growers have information they need manage soybean fields better in Illinois.

Work Student(s) will Complete: The student will learn about fertilizers, cropping systems, tillage tools, crop physiology, measuring plant parameters related to crop growth, harvesting and processing soybean samples, preparing samples for lab analysis, data management and analysis along with making figures/tables. The student will also be trained for presenting the results at scientific meetings as well as field days.

Number of students Needed: One

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Project Title: Assessing Cover Cropping and Double Cropping on Minimizing Nitrogen Losses and Soil Health in Corn and Soybean Production

Start Date: Ongoing **End Date:** Ongoing

Project Description: Illinois nutrient reduction strategy aims at reducing nitrate-N and P losses to waterbodies to minimize environmental footprints of agricultural practices. Two strategies that would help a farm stay profitable while reducing these nutrient losses are double cropping winter wheat with soybean and implementing cover crops. We aim at evaluating different nitrogen management during the wheat production for ensuring high crop production and quality, its environmental effects, and soil health over a four-year period. We currently are in the third year of the trial.

Work Student(s) will Complete: The student will learn about fertilizers, cropping systems, measuring, analyzing, and calculating nitrate-N and nitrous oxide emissions in field and laboratory. All soil health measurements will be assessed and the student will be trained for. The student will also be trained for presenting the results at scientific meetings as well as field days.

Number of students Needed: Two

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Project Title: Ground-Penetrating Radar Applications to Investigate Crayfish Burrowing and Ecology

Start Date: Ongoing **End Date:** Ongoing

Project Description: Ground-penetrating Radar (GPR) is a non-intrusive method of geophysical surveying to investigate a variety of subsurface objects and structures. For example archaeological sites, gravesites, caverns, groundwater, bedrock geology, and manmade infrastructure have been studied. This pioneering research explores using GPR to image subsurface crayfish burrows without inflicting any harm or damage. Ongoing SIU research is attempting to further improve these strategies and to develop 3D imaging to learn more about elusive crayfish burrowing and ecology below the surface.

Work Student(s) will Complete: Student(s) will join the IUS Ground-penetrating radar (GPR) research team during the spring semester and receive training. Afterwards and during the summer, student(s) will collect Ground-penetrating radar (GPR) data above endangered crayfish habitats. Students will then process, analyze, and interpret the GPR results. Students will present their results at a student symposium, and submit an abstract or summary for conference presentation and possible publication.

Number of students Needed: 1-3

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