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Board 322: Introducing Bio Mediated Methodologies in Geotechnical Engineering through Course-based Undergraduate Experiences (CUREs): Mitigating Fugitive Dust Effects by Using Urease in Enzyme Induced Carbonate Precipitation (EICP)

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Anna Martí-Subirana is a faculty member in the Biosciences Department at Phoenix College, where she teaches General Biology for Majors I (BIO 181) and BIO 247 (Applied Biosciences: Biotechnology), a course intended to prepare students for internships in bioscience and biomedical research labs. Born and raised in Barcelona (Spain), she has an MS in Molecular Biology and Genetics, and a PhD in Developmental Neurobiology from Universitat Autònoma de Barcelona (UAB). Dr. Martí-Subirana graduated and did postdoctoral work at UAB and later at Northwestern University and the University of Iowa College of Medicine focused on the role of glial cells during neuronal migration, and on genes and transcription factors that specify neuronal fate. As a STEM-CURE (NSF award 1832543) faculty, her responsibilities include introducing research projects in the undergraduate courses she teaches with a focus on improving STEM and STEM-related workforce skills and preparedness. Dr. Martí-Subirana also holds an MA in English and American Literature from Arizona State University; she is very active in the campus community in promoting interdisciplinary and collaborative projects that include industry, social and community awareness and service, humanities, science, engineering, and technology.

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Introducing Bio Mediated Methodologies in Geotechnical Engineering through Course-based Undergraduate Experiences (CUREs): Mitigating Fugitive Dust Effects by Using Urease in Enzyme Induced Carbonate Precipitation (EICP)

Introduction

Course-based Undergraduate Research Experiences (CUREs) are high impact practices that have been proposed as a strategy for increasing access to the educational benefits of research for a larger and more diverse student population [1], [2]. Embedded into the course curriculum, CUREs provide students with the opportunity to work collaboratively, to use iterative scientific practices, and to conduct research that is relevant to the society at large [3]. In spite of a large number of studies reporting the positive impact of CUREs on students enrolled in STEM 4-year programs, little is known about the benefits that CUREs have on students attending 2-year institutions [4]. CUREs represent a new paradigm in STEM education at community colleges. Community colleges have a dual mission; to prepare students for transfer and for entering the workforce. Despite a relatively high percentage of transfer degrees, a much smaller student percentage earns a Bachelor's degree. According to a recent nationwide study by the Community College Research Center (CCRC, Columbia University), only 33% of students enrolled in community colleges transferred to four-year institutions (2015 cohort) and fewer than half of those transfer students (48%) earned a bachelor's degree in six years. These numbers indicate that only 16% of community college students attained a bachelor's degree in six years, with lower rates, on average, for low-income, male, older, Black, and Hispanic students [5].

With the defined goal of identifying strategies for increasing community college transfer and to prepare students for industry and degree attainment (Bachelor's, Master's, or Ph D), building upon results and lessons learned from implementation of the NSF funded STEM-CURE Program (NSF HRD grant # 1832543) and NSF EES Planning grant # 2332525, Phoenix College (PC) STEM faculty are implementing and designing multidisciplinary CUREs (mCUREs) in their courses that can be continued as summer Research Experiences for Undergraduates (REUs) or research projects when students transfer to a four-year institution. Multifaceted societal problems can very unlikely be successfully solved using methods of one single discipline. Examples of multidisciplinary undergraduate research experiences reveal to be a valuable experience for engaging undergraduates with the concerns of their communities, the environment, and the society at large [6], [7]. The mCURE described here represents an example of such a multidisciplinary educational approach to STEM education.

Implementation of Bio Mediated Fugitive Dust Mitigation mCURE

Generation of fugitive dust is caused by natural phenomena or associated with civil construction, mining, and agricultural activities and it has significant economic, societal, and environmental consequences. Control of fugitive dust has got the attention of civil and geotechnical engineering alike, as it can deplete and contaminate natural water resources, alter geological characteristics, cause ecosystem degradation, and impact the health of communities [8]. Strategies for dust control based on naturally occurring or induced biological processes present a more sustainable alternative to traditional methods, especially those that rely on large volumes of water. Enzymes play a major role in mediating biochemical processes that are essential to all living organisms and can be used in engineering for beneficial purposes; for example, to control fugitive dust emissions by enzyme induced carbonate precipitation (EICP) using the enzyme urease [9], [10]. This course project attempts to analyze the efficacy of urease-mediated EICP on selected soil samples and experimental conditions by applying geotechnical engineering methods. Urease catalyzes the hydrolysis of urea (a common soil fertilizer) into ammonia (NH_3) and carbon dioxide (CO_2). Urease is a key participant in the nitrogen cycle, and it is commonly found in bacteria, algae, plants, fungi, and animal waste.

BIO 181 (Introductory Biology for Majors I) is a transfer course for science and engineering majors with a lecture and lab component. At PC, 10% of students enrolled in BIO 181 are pursuing engineering degrees. Approximately 25% of PC students completing engineering major requirements transfer to Civil Engineering programs. BIO 181 students are introduced to the problems associated with dust generation, to how EICP provides a more sustainable strategy for dust control, and to how urease can increase the rate of carbonate precipitation (and therefore soil crust formation) by a factor of 10^9. BIO Students have covered enzyme activity in class; they are asked to list environmental factors that can impact the efficacy of urease in catalyzing EICP and to design experiments to test them. In this particular experiment, different concentrations (1M, 1.5M, 2M) of urea (the substrate of the enzymatic reaction) were tested for optimal crust strength. All students enrolled in the lab course execute the project from start to finish: identification of variables, extraction of urea, making solutions, EICP protocols, testing for crust strength, analyzing results, and presenting conclusions. The project is done in collaboration with NSF funded Center for Bio-mediated and Bio-inspired Geotechnics (CBBG) at Arizona State University and supported by NSF award HRD # 1832543. CBBG faculty and students are invited to give an introduction to the topic and to stress its relevance to the community and society at large. The experiment expands for 6-8 weeks out of a 16- week semester.

Impact and Future Directions

The project was implemented for the first time in Fall 2023, and has continued in Spring 2024. Through this project, students gain a better understanding of enzyme activity, applications of bio mediation to environmental problems, interdisciplinary collaboration, engineering design (identifying the need, designing, evaluating, and improving a prototype), geotechnical engineering methods, soil classification, compressed soil crust strength testing, the process of science, and awareness of environmental problems that affect the health of their communities. In upcoming academic semesters, students will test the durability of the optimal treatment at different temperatures. Applying the treatment at different temperatures will assess the durability of it in natural environmental temperature conditions (extreme temperatures and day/night temperature changes).

The impact that this project may have on whether or not students consider previous major choices and decide instead to pursue an engineering major has not yet been assessed.

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