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CURES and the Microbiome

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Abstract: ***A significant problem facing higher education institutions is the inability to incorporate professional development training in the curriculum. Many pedagogical strategies have been developed in the last two decades to address this academic deficiency. Course - based undergraduate research experiences (CUREs) are an evidence - based approach with positive student outcomes. CUREs permit many science, technology, engineering, and mathematics (STEM) undergraduate students to participate in the scientific process and thus prepare students for the rigors of future graduate and professional school programs and careers. CUREs are a pedagogical and training method suitable for STEM departments of all sizes. They can accommodate smaller institutions that may have restrictive budgets and financial resources to offer authentic, faculty - mentored research experiences to most STEM matriculants. The animal microbiome and phytomicrobiome represent the total collection of microbes in animals and plants, respectively. Exploring microbial diversity and the functional attributes of microbes and microbial products in animals and plants presents an immeasurable number of CUREs student projects that can be developed. The conflation of CUREs and the field of microbiomics is a potentially beneficial marriage with advantageous results. Future educational research exploring the effects of animal microbiome and phytomicrobiome CUREs projects on student outcomes and other factors will assist educational researchers and STEM faculty.***

Keywords: CURES; animal microbiome; phytomicrobiome; training; evaluation

1. Introduction

Expanding the STEM undergraduate research community is essential to STEM faculty and institutional administrators. An extensive swath of educational research studies has investigated the effects of undergraduate research on many facets of student success in school and beyond [1 - 3]. A canonical objective for most STEM departments is the understanding that students who engage in research within their field gain invaluable skills and perspectives that lead to tremendous academic success and a better understanding of paramount job skills. Steep rises in the costs of operating and maintaining productive research labs on college campuses have made it more difficult for research advisors to support the professional training of many students consistent with the traditional faculty - mentor model. A practical, budget - friendly approach to address the challenges of student research training in academic settings is course - based undergraduate research experiences (CUREs).

CUREs represent a cure for STEM faculty contemplating approaches to establish or improve student access to faculty - mentored research engagement. CUREs are unique from traditional "cookbook" laboratory activities in many ways. Compared to CUREs, in conventional labs, the outcome is known in advance, and the experimental procedures often have been performed by thousands of students over the years using the same laboratory manual or procedures. CUREs, on the other hand, represent novel, relevant research experiences for which the outcome is unknown, like academic and industrial research environments. CUREs enhance scientific and collaboration skills and are iterative and promote ownership from discovering new knowledge. CUREs are a cost - effective approach that integrates basic, straightforward, or complex research projects within a particular course or curriculum [4]. This approach is beneficial because undergraduate research is embedded into a specific course, presumably required for graduation, allowing for greater student inclusion in the research enterprise. It is nearly impossible for prominent research institutions to allow every student to engage in laboratory research using traditional mentoring practices. Due to the high research costs, faculty - mentored research experiences are typically reserved for graduate students or undergraduates with exceptional talent, skills, and knowledge. Even for institutions with a much smaller student population, creating traditional apprenticeship - style research experiences for all students is not feasible. CUREs incorporation into specific lectures and laboratory courses mitigates the problem of student exposure to research activities.

In addition to the traditional benefits of conducting research, CUREs also allow for a better understanding of more nebulous concepts such as responsible and ethical conduct of research (RECR). RECR shines a spotlight on data integrity, intellectual property issues, and eliminating biases that interfere with advancement [5]. RECR is a concept that needs to be better understood by beginning student researchers. A fair amount of literature documents different types of CUREs implementations and associated effects. CUREs are different than traditional STEM laboratories in that the investigatory endeavors are based on original and relevant research topics with unclear outcomes and can expand STEM students' conceptual and practical knowledge of the scientific method. CUREs could be constructed by integrating quick exercise CURE - based modules that could take about 1 - 3 weeks to complete. More complicated CUREs could be completed in an entire semester (e. g., 13 - 16 weeks). CUREs can also be designed for multiple semesters and include several lecture and laboratory courses. While incorporating CUREs in the undergraduate curriculum is advantageous, DeChenne - Peters et al. [6] demonstrated that the length of the CUREs can impact student outcomes. Data showed that course - length CUREs had a more significant effect on career interests and desire to perform research in the future than short - length CUREs.

The current article offers recommendations on developing animal microbiome and phytomicrobiome CUREs. The animal microbiome refers to all the microorganisms and microbial genes confined to a particular location or ecosystem in animals. Studies on the animal microbiome typically focus on animal - microbe interactions and have traditionally focused on host - pathogen associations and, more recently, as potential treatment avenues for multiple diseases such as inflammatory bowel disease, cancer, and many metabolic disorders [7 - 9]. The phytomicrobiome refers to all the microorganisms and microbial genes associated with plants, plant structures, and plant support systems (e. g., soil). [10 - 12]. Analysis of the phytomicrobiome typically focuses on examining different types of plants, roots, seeds, and soils. Animal microbiome and phytomicrobiome projects generally utilize experimental designs, equipment, and protocols from microbiology, molecular biology, ecology, bioinformatics, computer science, and other disciplines [13]. The most accessible type of CUREs microbiome to design is isolating and identifying microorganisms in a particular animal or plant. Isolation and identification methods depend on the kind of culture conditions and other variables, which could be varied to generate different student research experiences.

Moreover, students could compare microbial composition in two or more specimens that differ in phenotype, genotype, life cycle, physiology, and tissue location (e. g., healthy/unhealthy, species 1/species 2, region 1/region 2). Using general microbiology techniques, students can extract and culture microorganisms and use molecular biology techniques such as polymerase chain reaction amplification of conserved bacterial and eukaryotic genes (e. g., ribosomal RNA genes) followed by nucleic acid sequencing or shotgun metagenomic sequencing and bioinformatic protocols to identify taxonomic groups. Additional downstream ecology (e. g., diversity indices) and genetics (e. g., bacterial genome assembly and functionality) procedures can be performed depending on access to equipment, technology, funding, services, and time. The selection of the precise research topic and examination procedures is entirely arbitrary. Using basic animal systems (e. g., invertebrates) and plant systems (e. g., grass, soils) to study the microbiome is an efficient way to accomplish the article's goals.

The aim for institutions that constantly struggle financially to budget the appropriate equipment for innovative STEM - based activities is sustainability. Selecting the appropriate research project topic and underlying research questions is essential for the sustainability of the CUREs. The advantages of the pedagogical and training approach described in this article are that animal microbiome and phytomicrobiome projects can be developed using an almost endless supply of free or very inexpensive biological specimens. Also, a faculty member or faculty team can elect to pursue attainable research goals based on their institution's resources. For example, undergraduate institutions with robust budgets and access to cutting - edge microbiome instrumentation may choose to design novel CUREs involving metagenomic, metabolomic, and proteomic protocols. In contrast, undergraduate institutions with anemic budgets and a small complement of biology instrumentation and bioinformatics technology may design novel CUREs based entirely on the ability to isolate, culture, and use phenotypic analysis to document microbial populations.

Animal Microbiome CUREs

The animal microbiome, particularly the human microbiome, has sparked great excitement over the last two decades [14 - 16]. Many federal and international microbiome projects have demonstrated a relationship between animal microbiome diversity and health and disease. Dysbiosis represents a discrepancy in an organism's typical microbial profile. Many factors cause this divergence in resident microbes, typically leading to abnormal biological functions, resulting in various morbidities. Moreover, animal microbiomes that either directly or indirectly produce pro - inflammatory or mimetic inflammatory compounds tend to exhibit harmful outcomes for the host organisms [17]. Since the gut microbiome contains the most microorganisms in animals, it is the most studied location. Animal microbiome projects can be designed and performed on various animals, including amphibians, birds, fish, invertebrates, mammals, and reptiles. Historically, basic animal microbiome research projects typically use essential animal models, including the fruit fly, mice, and zebrafish. However, Douglas [18] advises that other simpler animal systems can produce relevant findings.

Phytomicrobiome CUREs

Like the animal microbiome, the phytomicrobiome has seminal foundations on host - pathogen interactions [19, 20]. Also, as with the animal microbiome, alterations to the characteristic microbes on or in plant tissues are likely to impact the health and viability of the plant. Four significant plant regions are studied to examine plant - microbe interactions and other phytomicrobiome areas. The four regions are the phyllosphere, endosphere, rhizosphere, and soil. The phyllosphere describes the microbes located outside the plant and resides on the external surfaces of the plant growing above ground. The endosphere describes the microbes living within the internal plant tissues above ground. The rhizosphere, the root microbiome, describes the soil - root interface containing microbes. Since the soil and rhizosphere contain most of the microorganisms in plants, they are the most studied locations, and these sites provide unique benefits to reduce disease and enhance plant growth [21, 22].

2. Conclusion

There is nearly universal agreement that STEM undergraduate education improvements are continually needed to better prepare students for the ever - changing challenges of our time. Creating STEM undergraduate research pedagogical approaches that satisfy compliance with departmental objectives and student competency goals is vital at two - year and four - year colleges and universities in the United States. Exposing STEM students to beneficial molecular, microbiology, bioinformatics, and statistical protocols aligned with industry standards and research - intensive institutions is a critical mission, especially for community colleges and primarily teaching institutions. Technological advances have produced a more knowledgeable student body, one capable of accessing unlimited facts and statistics using one of many portable mobile devices. Since discipline - specific information retrieval is relatively easy, the onus for STEM faculty to transfer professional development skills has become a significant priority. Curricular aims in this decade are sharply focused on preparing students for careers in basic research or applied research careers.

Over the last few decades, several teaching strategies designed to get students to think like research scientists have emerged. Supporting evidence shows that CUREs are very effective tools to encourage proper development of the essential skills students need to succeed in demanding and lucrative STEM research careers. Limitations in on - campus research facilities and increasing demand for students to obtain real - world research experiences have made CUREs indispensable for STEM departments to meet the needs for relevant student research engagement. Further, a significant goal of CUREs is to enhance the feeling of ownership. As stated, many students have performed traditional laboratory exercises many times, and the data is highly predictable. With CUREs, students often generate data for the first time and derive a strong sense of ownership; this novel data is also purported to improve student satisfaction. Well - crafted and well - utilized CUREs rubrics will benefit student learning goals by clearly articulating expectations and performance indicators. CUREs rubrics must be designed through consensus from input from several members of a departmental unit to guarantee the generation of a comprehensive evaluation product. More educational research utilizing various experimental designs and statistical analyses is necessary to understand better how CUREs affect students academically and professionally. Additionally, more research is needed to investigate the potential impacts of CUREs on gender, discipline, course type, and institutional type. Comprehensive evaluation activities involving students, faculty, and administrators will continue to improve CUREs in STEM.

A highlight of microbiome - based CUREs is that there is an almost limitless number of projects that can be designed to study unexplored animal and plant systems. The development of more inexpensive and portable nucleic acid sequencing platforms has made exploring the animal microbiome and phytomicrobiome much more attainable. CUREs research projects could be as simple as determining the microbial composition of an economically vital crop or interesting insect species. CUREs could present as 1 - 3 - week exercise modules in a laboratory course, be created as an entire course, or be constructed to include multiple courses. Individual students could be assigned a unique organism (e. g., animal or plant), or a group of students could work together to simulate an actual research lab group commonly seen in academic settings. Consult the research literature to determine gaps in our knowledge and understanding of the animal microbiome and phytomicrobiome. This activity will aid in the selection of appropriate CUREs projects. Regardless of the type of integration, STEM departments should design animal microbiome and phytomicrobiome CUREs to enhance student development and outcomes. Moreover, since the research projects represent novel and unexplored topics, students can further their understanding of the scientific process and gain invaluable skills by writing publications and presenting their data at national and international scientific conferences.

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References

[1] Haeger H, Bueno E, Sedlacek Q. Participation in undergraduate research reduces equity gaps in STEM graduation rates. CBE - Life Sciences Education.2024; 23: 1 - 12.

[2] Capaldi M, Bugajski K, Goebbert B, Watters M, Slattery M. Improving retention of commuter STEM students through undergraduate research. Scholarship and Practice of Undergraduate Research.2022; 6: 14 - 22.

[3] Ghebreyessus K, Ndip E, Waddell M, Asojo O, Njoki P. Cultivating success through undergraduate research experience in a historically black college and university. Journal of Chemical Education.2022; 99: 307 - 316.

[4] Buchanan A, Fisher G. Current status and implementation of science practices in course - based undergraduate research experiences (CUREs): A systematic literature review. CBE Life Sciences Education.2022; 21 (4): 1 - 17.

[5] Monthofer E, Ito J, Battaglia S, Diaz - Martinez L. Responsible and ethical conduct of research (RECR) diagnostic survey using case scenarios from biology course - based undergraduate research experiences (CUREs). Journal of Microbiology & Biology Education.2023; 24 (3): 1 - 10.

[6] DeChenne - Peters S, Rakus J, Parente A, Mans T, Eddy R, Galport N et al. Length of course - based undergraduate research experiences (CURE) impacts student learning and attitudinal outcomes: A study of the malate dehydrogenase CUREs community (MCC). Public Library of Science One.2023; 18 (3): 1 - 33.

[7] Manos J. The human microbiome in disease and pathology. APMIS.2022; 130 (12): 690 - 705.

[8] Hoffmann A, Proctor L, Surette M, Suchodolski J. The microbiome: The trillions of microorganisms that maintain health and cause disease in humans and companion animals. Veterinary Pathology.2016; 53 (1): 10 - 21.

[9] Ratiner K, Ciocan D, Abdeen S, Elinav E. Utilization of the microbiome in personalized medicine. Nature Reviews - Microbiology.2024; 22 (5): 291 - 308.

[10] Chouhan G, Verma J, Jaiswal D, Mukherjee A, Singh S, Pereira A et al. Phytomicrobiome for promoting sustainable agriculture and food security: Opportunities, challenges, and solutions. Microbiological Research.2021; 248: 1 - 11.

[11] Flowers L. Phytomicrobiome systems affect plant health and crop production. International Journal of Science and Research Archive.2023; 8: 1024 - 1029.

[12] Wani A, Akhtar N, Singh R, Chopra C, Kakade P, Borde M et al. Prospects of advanced metagenomics and meta - omics in the investigation of phytomicrobiome to forecast beneficial and pathogenic response. Molecular Biology Reports.2022; 49 (12): 12165 - 12179.

[13] Flowers L. Microbiomics research applications. International Journal of Science and Research.2023; 12, 1658 - 1661.
[14] Berg G, Rybakova D, Fischer D, Cernava T, Vergès M, Charles T et al. Microbiome definition re - visited: Old concepts and new challenges. Microbiome.2020; 8 (1): 1 - 22.
[15] Davenport E, Sanders J, Song S, Amato K, Clark A, Knight R. The human microbiome in evolution. BMC Biology.2017; 15 (1): 1 - 12.
[16] Peixoto R, Harkins D, Nelson K. Advances in microbiome research for animal health. Annual Review of Animal Biosciences.2021; 9: 289 - 311.
[17] Alberca G, Cardoso N, Solis - Castro R, Nakano V, Alberca R. Intestinal inflammation and the microbiota: Beyond diversity. World Journal of Gastroenterology.2022; 28 (26): 3274 - 3278.
[18] Douglas A. Simple animal models for microbiome research. Nature Reviews.2019; 17 (12): 764 - 775.
[19] Montesinos E. Pathogenic plant - microbe interactions. What we know and how we benefit. International Microbiology.2000; 3 (2): 69 - 70.
[20] Malmstrom C, Martin M, Gagnevin L. Exploring the emergence and evolution of plant pathogenic microbes using historical and paleontological sources. Annual Review of Phytopathology.2022; 60: 187 - 209.
[21] Quiza L, St - Arnaud M, Yergeau E. Harnessing phytomicrobiome signaling for rhizosphere microbiome engineering. Frontiers in Plant Science.2015; 6: 1 - 11.
[22] Jiao X, Takishita Y, Zhou G, Smith D. Plant associated rhizobacteria for biocontrol and plant growth enhancement. Frontiers in Plant Science.2021; 12: 1 - 8.