



A New Approach to Collaboration: A Partnership between an NSF-funded Engineering Research Center and a Liberal Arts College

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Introduction

In August 2016, the authors, faculty members at Lafayette College, were awarded a National Science Foundation (NSF) grant (Grant No. CMMI-1632963) based on an unsolicited proposal to the NSF's CMMI Division. Like many faculty at strictly undergraduate institutions, we routinely provide opportunities for students to work on research projects and fund this research in some situations through external grants. An innovation in this particular grant was the creation of a research collaboration between faculty and students at Lafayette and an NSF-funded Engineering Research Center (ERC). As stated on the NSF website, "The goal of the ERC Program is to integrate engineering research and education with technological innovation to transform national prosperity, health, and security." To accomplish this goal, collaborations between ERCs and other institutions are inherent in the work of an ERC; however, research collaborations between ERCs and small liberal arts colleges are rare and we know of no other collaboration of this type.

In our most recent research project, we have developed and implemented a model that successfully provides our students and ourselves with opportunities to collaborate on an interdisciplinary research project with faculty, researchers, and graduate students at the NSF-funded Center for Bio-mediated and Bio-inspired Geotechnics (CBBG). This paper provides a brief overview of the goals of the research project and describes our motivation for establishing the collaboration, the structure of the collaboration, the anticipated broader impacts associated with the work, and the results from the first 18 months of the partnership. A logic model is included to illustrate the connections between the resources, strategies, outcomes, and long-term impacts associated with the collaboration.

The goal of this paper is to describe the collaboration between Lafayette College and the ERC from the point of view of the faculty members at Lafayette, to describe the positive outcomes that have resulted from this collaboration, and to encourage faculty members at other small colleges to consider developing similar collaborations.

Research Goals

We are tenured faculty members in the areas of civil engineering and biology. Our research collaboration began in 2003 and was supported initially by an NSF grant that was funded between 2004 and 2006. Between 2006 and 2014, one of us took a full-time administrative role at the college while the other continued to conduct related research. At the end of the administrative commitment, we decided to re-engage our research collaboration efforts.

The goal of the research project funding by our current NSF grant is to advance knowledge regarding the use of biofilm-forming bacteria as a soil treatment to reduce soil permeability. Specifically, the work involves the development of biofilm in sand columns and the manipulation of nutrients, flow rates, and the use of a quorum sensing inhibitor to control the

location and growth of the biofilm. If successful, this research will result in the development and demonstration of a process that uses native bacteria to uniformly reduce the permeability of soil over a length of at least one meter.

Motivation for Collaboration with an NSF-funded Engineering Research Center

Undergraduate research experiences are known to benefit students ([1], [2], [3], [4], and [5], among others). Lafayette College, like many small liberal arts colleges, prides itself on an ability to offer research experiences to students. The latest National Survey of Student Engagement results for the college indicate that, “By their senior year, 50% of students have done research with a faculty member” (web link to be provided in final paper). Research experiences for students also benefit faculty members at small colleges by keeping the faculty members engaged in their areas of expertise; many small colleges, including ours, also consider continuing engagement in research when evaluating a faculty member for tenure and promotion.

While planning our most recent research collaboration, we were aware of a new NSF Engineering Research Center (ERC) with an overarching mission directly related to the research we wanted to conduct – the Center for Bio-mediated and Bio-inspired Geotechnics (CBBG). As stated on their website (<https://cbbg.engineering.asu.edu/about/>), the “CBBG applies biogeotechnical techniques to create sustainable, resilient, and environmentally compatible solutions for construction, repair, and rehabilitation of civil infrastructure systems.”

We realized that a collaboration with the ERC could have significant benefits. First, a collaboration would allow us to integrate our research with that of the investigators at the CBBG in an emerging frontier of science and engineering and the collaboration would create an exchange of information that would allow us to develop our research activities in cooperation with the CBBG. Second, a collaboration would connect our undergraduate students to CBBG resources and to the CBBG’s graduate students, researchers, and industry partners, and thereby expose our students to research experiences well beyond our college. And third, a collaboration would potentially help us to identify new questions that we might then be able to pursue in the future. Therefore, we decided to write a proposal to NSF that would not only support the research we wanted to conduct but would also support a collaboration among the new ERC, our students, and ourselves.

Structure of Collaboration

Because of our record of research in the area of bio-modification of soils, we knew researchers associated with the newly funded CBBG who were conducting research in a related area. We reached out to these colleagues and explained the collaboration we hoped to create. Because ERCs are expected to develop and support numerous education and outreach efforts, our colleagues saw potential benefits of the collaboration for the CBBG and we began work with the ERC’s leadership to develop a structure for the collaboration.

The laboratory portion of the activities funded by the grant are scheduled during the academic year, i.e., the funded research efforts occur when the undergraduate students are on our campus during the academic semesters and during the interim session between the fall and spring

semesters. These activities would occur with or without the collaboration but are augmented by the collaboration activities described below.

The collaboration activities funded by the grant include the following:

- Summer research experiences (including housing and pay) for two undergraduate students to participate in CBBG training for summer undergraduate researchers and also to spend approximately eight weeks at a CBBG institution working with CBBG students and researchers on ongoing CBBG projects.
- Participation in the annual CBBG meeting by two students each year to present their summer research projects.
- In-person meetings between the PIs and CBBG researchers each year—the PIs travel during the summer for an extended meeting at the CBBG institution where their students are spending the summer and the PIs also travel to the annual CBBG meeting and/or the mid-year CBBG meeting.

In addition, there are collaboration activities that occur but that are not funded by the grant. These activities include the following:

- Video conferences including the PIs, undergraduate research students, and CBBG researchers scheduled weekly during the summer and bi-weekly to monthly during the academic year.
- CBBG support to identify and obtain housing for undergraduate researchers each summer.
- CBBG support to create summer research opportunities for undergraduate researchers.
- Travel by one CBBG researcher each year to visit the PIs institution.

Outcomes Associated with Intellectual Merit and Anticipated Broader Impacts

A logic model for the collaboration, showing a summary of the collaboration resources, strategies, outcomes/outputs, and anticipated long-term impacts of the grant is shown in Table 1. Table 2 provides a summary of the grant's anticipated outcomes/outputs and evidence of achievement of those outcomes/outputs of the grant (as of Mar. 13, 2018) with respect to both intellectual merit and anticipated broader impacts.

This summary shows that, as of the writing of this paper, the grant has resulted in outcomes/outputs that provide strong evidence that the goals of the project are being accomplished.

Discussion and Conclusion

Faculty members at smaller institutions are often expected to be active researchers and to involve students in that work; however, higher teaching loads and service expectations may make it difficult for faculty members to maintain active research networks and programs. If a faculty member's research can be connected to a larger research organization, as demonstrated by the

collaboration described her, that collaboration can be a benefit to the faculty members at the smaller institution and their students.

Given the positive impact of this collaboration on the students and faculty at one small liberal arts college, it seems likely that the extension of this model to other ERCs as well as collaborations between faculty at small liberal arts colleges and large, research-intensive institutions would be productive in moving a particular research area forward. Collaboration also with large research institutions not just ERCs.

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Table 1. Logic model for collaboration.

Inputs/Resources	Strategies	Outcomes/Outputs	Long-Term Impact
<p>NSF funding (Grant No. 1632963)</p> <p>Lafayette College (LC)</p> <ul style="list-style-type: none"> EXCEL student support (pay for students not covered on the grant and housing for students during the January) Technical shop support Laboratory space and administrative support <p>CBBG</p> <ul style="list-style-type: none"> CBBG researchers' collaboration efforts and time Video conferencing coordination Summer training and housing logistics for LC students Involvement of LC students in summer research 	<p>Conduct research</p> <p>Recruit, involve, and mentor undergraduates</p> <ul style="list-style-type: none"> In grant-funded research In related independent research projects (e.g., honors thesis work) In options for graduate study and employment <p>Coordinate and collaborate (LC and CBBG) through regular video conference calls</p> <p>Travel</p> <ul style="list-style-type: none"> Undergraduate students to participate in REU training and summer research at CBBG universities LC faculty researchers to participate in CBBG meetings and to visit CBBG universities <p>Expose CBBG graduate students and researchers to research opportunities at PUIs</p>	<p>Research publications and presentations</p> <p>LC faculty development beyond grant funding</p> <ul style="list-style-type: none"> Initiating new research Continuing involvement with CBBG researchers <p>Student involvement</p> <ul style="list-style-type: none"> Numbers Disciplines Diversity <p>Student outcomes</p> <ul style="list-style-type: none"> Continued research involvement beyond grant funding Applications/acceptance to graduate programs <p>CBBG graduate student and researcher development</p> <ul style="list-style-type: none"> Expressions of interest in teaching and research at PUI institutions and/or involving more PUI faculty in CBBG research projects 	<p>Contributions to knowledge regarding engineering applications of biofilm formation in soil</p> <p>Workforce development</p> <ul style="list-style-type: none"> short-term through students involved in project long-term through the future impact of the students, PUI faculty, and researchers involved in the project <p>Development and proliferation of a successful model of collaboration between NSF funded ERCs and PUIs that supports the development of undergraduate and graduate students and increases research collaborations and capacity</p>

Table 2. Grant outcomes/outputs and evidence of achievement as of 3/13/2018.

Anticipated Outcomes/Outputs	Evidence of Achievement as of 3/13/2018
<i>Intellectual Merit</i>	
Research	<ul style="list-style-type: none"> • One presentation has been given on the research at a campus research event. • Four presentations have been given on the research and the collaboration efforts including two presentations by undergraduate researchers to industry partners and others at the annual CBBG meeting. • One provisional patent has been filed as a direct result of the research project.
<i>Broader Impacts</i>	
Establish collaboration between CBBG and Lafayette College	<ul style="list-style-type: none"> • Approximately 20 video conference meetings have been conducted between students and faculty members at the college and students and faculty members at the CBBG
Faculty development	<ul style="list-style-type: none"> • The PIs have traveled to the CBBG’s mid-year meeting in April 2017 and to the CBBG’s annual meeting in October 2017. • The PIs traveled during summer 2017 for an extended visit to the CBBG institution where their undergraduate students were located.
Undergraduate student involvement	<ul style="list-style-type: none"> • Seven undergraduate student researchers have participated on the project during the 2016-17 and 2017-18 academic years through a combination of grant funding and institutional funding. These students have included three biology students and four civil engineering students. Six of the students are female. • Two students have participated in a summer research experiences including training at one of the CBBG institutions and involvement in two research projects at a separate CBBG institution.
Undergraduate student continued interest in research	<ul style="list-style-type: none"> • The two students who participated in the summer research experience are completing year-long independent research projects at their college and each are planning to attend graduate school after receiving their bachelor’s degrees and have applied to multiple graduate programs.
CBBG graduate student interest in teaching and research at a PUI	<ul style="list-style-type: none"> • One CBBG graduate student has visited the PIs’ institution. • Three CBBG graduate students made unsolicited inquiries to the PIs about the combination of teaching and research at a small college