PROMOTING PARTNERSHIP, CULTIVATING COLLEAGUESHIP: THE SUMMIT-P PROJECT AT NORFOLK STATE UNIVERSITY

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ABSTRACT
Norfolk State University (NSU) is the only public Historically Black College and University (HBCU) member institution in SUMMIT-P. At NSU, a strong collaboration between the Department of Mathematics and its partner discipline, the Department of Engineering, has been established for the Calculus I and Differential Equations classes as part of the SUMMIT-P project. In this paper, we record a brief history of this collaboration project at NSU, the various structures within the SUMMIT-P Project, the site visit that occurred in Spring 2019, and how recent activities helped guide the direction of the project at NSU.

KEYWORDS
collaboration, partner discipline, fishbowl, site visit, engineering applications

What does it take to teach mathematics effectively to engineering students in a public Historically Black College/University (HBCU) like Norfolk State University (NSU)? Since a strong foundation in mathematics is necessary to be successful in upper-level engineering courses, how can mathematics faculty help engineering students appreciate and gain core mathematical knowledge? What are some concrete curricular actions that mathematics and engineering faculty can adapt to improve student success and retention? These are some questions that motivated our project, which is part of a National Consortium for Synergistic Undergraduate Mathematics via Multi-institutional Interdisciplinary Teaching Partnerships (SUMMIT-P). The project team at NSU, which consists of faculty from the mathematics and engineering departments, has the overall goal of helping engineering students become successful in their mathematics courses while also preparing them for future engineering courses. In the spirit of the Mathematical Association of America's Curriculum Renewal Across the First Two Years (CRAFTY) project (Barker & Ganter 2004; Ganter & Haver 2011), we strive to promote partnership and cultivate colleagueship between the mathematics and engineering departments in the College of Science, Engineering, and Technology (CSET), hoping that perspectives and applications from outside the mathematics classrooms will influence vital changes towards a mathematics curriculum that will provide a solid foundation for undertaking upper-level courses.

The Curriculum Foundations reports (Barker & Ganter, 2004; Ganter & Haver, 2011), which were developed as part of CRAFTY, included recommendations that were distilled from the work of several collaborative workshops that took place between 1999 and 2001. Regarding classroom skills, the recommendations for the mathematics community included: emphasize conceptual understanding, problem-solving skills, mathematical modelling, communication skills, and balance between perspectives (i.e., continuous vs. discrete, linear vs. nonlinear, etc.). Regarding instructional techniques, the recommendations include: use a variety of active learning methods, use appropriate technology, and improve interdisciplinary cooperation. Embracing the spirit of these recommendations, the NSU Department of Mathematics aims to provide high quality and relevant mathematics courses to serve our HBCU students.

The SUMMIT-P consortium (see www.summit-p.com for more information) is a collaboration between ten universities nationwide with an overarching goal to revise and improve the curriculum for lower division undergraduate mathematics courses, with a focus on the content and skills needed for student success in partner discipline fields. The collaboration happens in two levels: an intra-collaboration among member institutions and an inter-collaboration between selected departments in each member institution.

This paper is organized as follows: first, we record the history of SUMMIT-P at NSU; second, we narrate the highlights of the site visit; third, we describe the next steps in the SUMMIT-P programmatic structure, starting in Fall 2019; and fourth, we share some reflections on what we have learned thus far, highlighting the effectiveness of integrating classes and team-teaching in achieving our SUMMIT-P goals.

Brief History of SUMMIT-P at NSU

Joint Departmental Summit

The SUMMIT-P project at NSU began with a joint department summit between the faculty in the Departments of Mathematics and Engineering in Fall 2016. All full-time faculty from both departments were invited to attend the summit. The four-hour summit began with the

introduction of the project goals and objectives, followed by a fishbowl activity (Hofrenning, et. al, 2020). The main goal for the first semester of the project was to establish a Faculty Teaching and Learning Community between the two departments.

Throughout the summit, the leadership team reiterated the vital role that the partner discipline, engineering, plays in the success of the project. It was, hence, imperative that the partner discipline feel free to express their likes and dislikes as they related to the mathematics curriculum and the prerequisite knowledge their majors develop in courses such as College Algebra, Trigonometry, Calculus, and Differential Equations, which are the required mathematics courses for success in upper-level engineering courses. The team implemented the fishbowl activity to learn about the wants and needs of engineering faculty. In this activity, mathematics faculty served as silent partners. They gathered around a group of seated engineering colleagues while they articulated their concerns with their students' mastery level of certain mathematical concepts. The engineering faculty shared a list of mathematical topics they hoped would be covered in entry-level mathematics courses. The mathematics faculty tried to absorb and understand their colleagues' wish list. Some of the topics in the engineering wish list included conic sections, trigonometric functions and equations, solving for variables in a literal equation, and interpreting graphs. The fishbowl activity proved to be the most productive part of the joint department summit.

Pilot Courses

In Spring 2017, the leadership team decided that sections of Calculus I for engineering majors would be revised through the SUMMIT-P project. Since this would be the first course that the project would focus on, a member of the leadership team assumed the responsibility of teaching the course and implementing some of the recommendations gathered during the joint department summit. This course includes a one-hour session per week for students to engage in problem-solving or attend engineering presentations. The SUMMIT-P team member administered the problem-solving sessions, choosing specific examples that addressed some of the recommendations gathered during the previous semester's summit. For example, when the course content featured finding tangent lines to curves, the instructor drilled the students on finding horizontal tangent lines for trigonometric curves. As a result, during the problem-solving session, students were solving calculus problems using precalculus concepts that were identified as student weaknesses by engineering faculty during summit. During other weekly one-hour sessions, engineering faculty delivered presentations on engineering applications of calculus. Over time, this aspect of the course has evolved into a series of organized presentations delivered by faculty and graduate students from both departments. These presentations are given in either the regularly scheduled classroom or in an engineering laboratory.

In Fall 2017, the focus of the project shifted to the topics in Differential Equations due to their importance in modeling engineering applications in virtually every area of engineering. The leadership team realized the possibility of presenting common applications in both the sections of Calculus I for engineering majors and in Differential Equations. Since many applications modeled using differential equations can be discussed in a calculus course without the need for a detailed discussion of the mathematical modeling, including these applications in both courses helps to make meaningful and useful connections between the courses for students. For example, an engineering-focused modeling application was presented as a topic of discussion in the Differential Equations course, while significant class time was spent developing and analyzing

the solution to the same application in sections of Calculus I for engineering majors. To date, this shared application course feature remains as one of the effective program structures implemented as a result of the NSU SUMMIT-P project. We subsequently focused on improving these courses.

New Leadership Team

The departure of one of the members from the initial project leadership team warranted formation of a new leadership team. Maintaining the original team composition, two mathematics faculty and one engineering faculty began their service in February 2019. The new team immediately commenced work to prepare for a site visit in April 2019. The site visit, one of the SUMMIT-P consortium's essential program structures, is where faculty from one member institution visits another member institution (Piercey, et. al, 2020). The new NSU leadership team used this opportunity to re-examine and revitalize the program at NSU, ensuring that the aims of the consortium will continue to be actualized. Without a doubt, the site visit was the impetus that inspired the NSU team to show that effective collaboration can translate ideas into action.

Site Visit at NSU

During the site visit in Spring 2019, the Virginia Commonwealth University (VCU) leadership team and members of the grant management team from Embry-Riddle Aeronautical University (ERAU) and Appalachian State University (ASU) visited NSU for two days. The visitors attended the sessions of courses that had been revised during the first two years of the project, interviewed students taking the courses, met with NSU administrators, held discussions with faculty from both departments, and most importantly, engaged in a deep conversation with the NSU leadership team. Table 1 provides a brief overview of the site visit events:

Table 1
Site Visit Schedule for Spring 2020

Day 1	
	Classroom Visit I – College Algebra
	Discussion with students
	Luncheon with NSU administrators and CSET faculty
	Classroom Visit II – Combined sections of Calculus I and Differential Equations
	Discussion with Mathematics and Engineering Faculty
Day 2	
	SUMMIT-P Meeting between leadership team and site visitors

Teaming Up with Another NSF Grant

At the start of the Spring 2019 semester, even before preparations were made for the site visit, the SUMMIT-P leadership team collaborated with a group of NSU mathematics, biology, and chemistry professors who were working on a National Science Foundation funded grant project, Targeted Infusion Project: Engaging Students for Higher Retention and Building Stronger Foundations in Pre-Calculus Using the Flipped Model (NSU-TIP), to address the

mathematics deficiencies of students majoring in biology and chemistry. Poor performance on the university placement test derailed most biology and chemistry majors from graduating within four years. They noticed that, like students majoring in engineering, incoming biology and chemistry majors failed to understand the important connections between mathematics and physical science disciplines. As a result, even those who successfully completed introductory level courses like College Algebra did not perform well in general chemistry courses.

True to the spirit of collaboration and partnership, the NSU SUMMIT-P and NSU-TIP leadership teams decided to work on a course aimed to support the objectives and initiative of both projects. The result of this collaboration was the creation of sections of a three-credit College Algebra course for biology majors and a one-credit College Algebra Lab for biology majors. The laboratory course has been taught by a member of the SUMMIT-P leadership team since it was first introduced. Like the pilot Calculus I sections described above, one of the goals of this laboratory course is to provide a platform for professors in disciplines other than mathematics to present applications of mathematics in biology and chemistry. By the end of the Spring 2019 term, nine different presentations were made by biology and chemistry professors, and five applications were presented by the students enrolled in the laboratory course.

During the site visit, the visitors attended two classes, including a section of College Algebra Lab for biology majors. The session covered an application about creosote exposure of fish and other creatures in the Elizabeth river and was team taught by mathematics and biology faculty. Through this collaboration, the biology faculty demonstrated the use of mathematical concepts in performing biology experiments. For instance, using some laboratory equipment, the biology faculty demonstrated and explained certain issues in the laboratory that can be solved using correct unit conversion procedures and understanding scales of magnitude. The mathematics faculty highlighted the importance of the mathematics concepts during the demonstration. The duo concluded their presentation by posing a question to the students: “Why should a biology major study mathematics?”

The official partner discipline of NSU SUMMIT-P is engineering and the mathematics courses that are the primary focus of the project are Calculus I and Differential Equations. It should be noted, College Algebra Lab for biology majors is not part of the project. However, due to the small size of our mathematics department and the fact that members of the leadership team have connections with faculty that are involved in NSU-TIP grant, we decided to use the site visit as an opportunity to work on and get feedback on both projects. This decision allowed us to accomplish objectives for both projects and show to the site visitors the kind of collaboration that exists at our university. We plan to include biology or chemistry as partner disciplines in future projects.

Two Math Classes, One Engineering Lab

During the site visit, visitors observed another class that gave them the opportunity to interact with students taking Calculus I and Differential Equations. During this class session, each student in Differential Equations, a junior level course at NSU, was paired with a student taking Calculus I to analyze a circuit using the Digilent Analog Discovery Design kit and MATLAB/Simulink computing software. A short lecture by the course instructor on solutions of a second-order differential equations set the stage for a presentation by an engineering faculty member on the design and analyses of certain circuits. What happened next was so promising that the SUMMIT-P leadership team decided to make the activity an integral part of both

courses. The synergy between the faculty and students made for such a productive class. The Calculus I students, eager to learn from the upperclassmen, continuously asked questions and received advice about the mathematical concepts that are necessary to succeed in engineering courses. Faculty reported overhearing advice from upperclassmen such as "make sure that you know how to interpret graphs because you will need this in your engineering labs."

It is well-documented that an active learning experience in mathematics is one of the most effective ways to help address both the learning issue and the diversity issue in a mathematics classroom (Herzig, 2005). Furthermore, in an HBCU mathematics classroom, students learn best when they have the chance to engage socially (Ross, 2014). We are pleased to report that we were able to verify that an active learning experience coupled with social engagement was effective in helping our students appreciate the Calculus I course topics. Moreover, with such a discipline-specific context, we were able to provide a learning experience to the Calculus I students that will hopefully increase their elementary mathematics abilities, enabling them to transfer skills from Calculus I to their engineering courses.

Insights from the Outside

The site visit concluded with a lengthy conversation between the NSU SUMMIT-P leader and visitors about approaches to strengthen the existing mathematics-engineering learning community and the overall quality of the project at NSU. The two-hour brainstorming session that took place proved to be beneficial to the host institution. To engage a greater number of engineering faculty in the SUMMIT-P project, the visitors suggested that faculty pairs be formed, one member of the pair from each department, to collaborate on developing an original engineering application.

The Next Steps

The NSU SUMMIT-P leadership team was encouraged to design two additional program structures in the form of workshops to further strengthen the connection between the mathematics and engineering departments. The first workshop took place at the end of the Spring 2019 semester and a second workshop was scheduled prior to the Fall 2019 semester. Like many other program structures, these workshops are active processes that aim to promote partnership and cultivate colleagueship between the two departments.

Spring Workshop for Consultants

Four faculty from each of the departments were invited to a two-hour workshop to learn about becoming an NSU SUMMIT-P faculty consultant. Consultants are faculty who create application modules that utilize and showcase their academic research expertise. A big part of this workshop followed a modified "speed-dating" activity in the following way: the eight faculty members were divided into four groups, and each group was given ten minutes to talk about their research interests and teaching experiences. The leadership team decided to impose a time limit so that the faculty participants would focus on the salient points of their research and teaching experiences. After ten minutes, the teams were rearranged to allow for meeting other participants. At the end of the speed-dating activity, the mathematics faculty were asked to leave the room while the leadership team gathered opinions from the engineering faculty. In the end, the leadership team decided on which faculty to pair to co-develop activities. With eight faculty

consultants, we formed four faculty pairings based on the following guidelines: pair a senior faculty member with a junior faculty member, match the professional personalities and teaching styles, and align the research interests as close as possible. The first guideline had a bonus effect of providing a mentoring opportunity for the pairs, while the third encouraged possible research partnerships. The second guideline, arguably subjective in nature, was introduced to ensure a productive and supportive relationship.

Creating Curriculum Content

Within this faculty consultant program structure, each member of the pair had specific responsibilities. The main task for the engineering faculty member was to suggest various engineering applications in which mathematical concepts play pivotal roles in the modeling process. The main task of the mathematics faculty member was to make sure that the developed lesson modules were written and planned in such a way that they would complement and supplement the existing mathematics curriculum and syllabi of the course the application would be used in. The goal was for each pair to create a lesson module that could be used in one or more of the following courses: Pre-Calculus, Calculus I, or Differential Equations.

Table 2
Timeline for Completion of Intended Tasks During Year 3

Task to be completed	**Due Date**
Teaching abstract of application module—submitted for review by the NSU SUMMIT-P team	7 June, 2019
Results of the review	14 June, 2019
Lesson plan completed	19 August, 2019
Powerpoint prepared	23 August, 2019
Classroom presentation by engineering faculty	Fall semester

The lesson module had to feature an engineering application of mathematics concepts. The intent was that the application would be related to the engineering faculty member's own research or be an application studied in an upper-level engineering course. Each team was expected to submit an instructional abstract, a lesson plan, a PowerPoint presentation, and a few assessment tools for their proposed lesson module. The abstract requirements were an engineering-based motivation for the project or application, a classroom implementation plan, and expectations for the students. It also needed to specify the mathematics topics that would be covered in the lesson and the level of understanding that students would need to successfully work with the content. The lesson plan included a list of required equipment, tools, or software, the time to complete the activity, and some assessment tools. The assessment tools took the form of a worksheet, quiz, essay prompt, mini-project, etc. The expectation was that the materials should provide all of the information that course instructors would need to be able to deliver the lesson by following the step-by-step instructions to guide students through a 40-minute activity. The PowerPoint instructions were to be student-friendly and contain the salient points of the lesson plan. The lesson plan was intended to serve as a guide for the instructors, while the PowerPoint served as a study guide for students' use.

Table 2 shows the timeline for the completion of the tasks. The NSU SUMMIT-P leadership team made sure that the faculty consultants understood the project expectations from the start. The leadership team accomplished this by establishing solid communication channels

during the summer and requiring the teams to submit teaching abstracts before proceeding to the next steps in the module development. The teaching abstracts were carefully reviewed by the leadership team, checking for overlaps between the ideas presented by different pairs and originality of the engineering applications and ensuring that the proposed classroom implementation plan was viable and sustainable. We plan to publish a compilation of the application modules in the form of a teaching manual to be used as a supplementary course material for interested faculty.

The faculty consultants met a couple of times during summer, and members of the leadership team joined one of these meetings. The leadership team recognized that the faculty consultants would not be able to meet and work on the project during the regular semester.

One interesting application module that was approved by the NSU SUMMIT-P leadership team for use in Calculus I and Differential Equations involved a system of differential equations to model and analyze a wireless power transfer. The engineering professor on the faculty consultant team is an expert in wireless communications. Another interesting lesson module that was developed was an activity that featured analyzing the human heart's electrical behavior using data from electrocardiograms (ECGs). The engineering professor on the team who developed the module is an expert in bio-medical engineering. These two modules were incorporated in the section of Calculus I for engineering majors during Fall 2019. Faculty pairs worked together to deliver a 45-minute presentation about the module, including a short motivation video, a brief lecture using the prepared PowerPoint slides, and an in-class, hands-on activity. They made sure to exemplify respectful communication, took turns in explaining their lesson, and supported each other while in front of the class.

By planning and working together during the summer to develop the modules, we hoped to unite the two departments in the purpose of increasing the engineering majors' awareness about the direct connections that exist between the two disciplines. We succeeded in accomplishing this objective.

Summer Workshop on the Syllabus

Before the Fall 2019 semester began, the NSU SUMMIT-P leadership team and all eight faculty consultants met for a one-day follow-up workshop, where the consultants delivered short presentations about their application modules. The leadership team reviewed all the materials and made recommendations for refinements and improvements.

Furthermore, the event was an opportunity for faculty to discuss and revise the existing curriculum and syllabi for Pre-Calculus, Calculus I, and Differential Equations. Since the course coordinators for these courses served as faculty consultants and the chair of the mathematics department served as the NSU SUMMIT-P Principal Investigator, implementing changes to the syllabi was made possible in a more efficient way. Such advantages and logistical efficiencies are possible in a small institution.

What We Learned

This section highlights some insights and realizations that we learned as one of the main proponents of collaborative teaching explorations in our university. In particular, we record some of the benefits and challenges of integrating classes, team-teaching, student assessment, and presentation evaluations.

Integrated Classes

What happens when a laboratory session attended by students in Calculus I and Differential Equations and a specially developed engineering application module is the focus of the lesson? Our experience at NSU revealed many benefits for the students, most notable of which was the increase in peer engagement and classroom participation. Teaching the integrated class required significant preparation and extensive collaboration among the Calculus I and Differential Equations professors and the faculty presenters. Three different topics were covered in a 45-minute session. For example, when we implemented this integrated class structure in Fall 2019, the Calculus I students were learning curve sketching techniques using derivatives, the Differential Equations students were learning second-order differential equations with constant coefficients, and the faculty presenter's topic was simulating solution responses to circuits using differential equations. In order for this one laboratory session to be successful, the faculty invested significant time and effort in preparing the syllabi, students, and laboratory. As a bonus, we had considerable advantage on the scheduling aspect, since the project Principal Investigator, as the department chair, was the responsible party for the scheduling of mathematics classes. Going forward, we intend to explore further the possibility of more regular interaction of freshmen with upperclassmen through combined application sessions.

Team Teaching

Collaborative team-teaching is an important structure of the NSU SUMMIT-P program. Students reported that the presence of an engineering professor in a Calculus I course provided curricular coherence between mathematics and engineering courses. During the site visit, they also reported that hearing a mathematics faculty utter the words "I honestly did not know that algebra has so many concrete applications in biology" while inside a mathematics classroom made them realize that learning is a continual process, even for those with PhDs. This epiphany would likely not have occurred in a traditional lecture course without a team-teaching model.

Aside from the novelty of having another professor deliver lecture materials, students also appreciated the fact that the team-teaching faculty were exemplifying collaboration and respectful classroom communication. From the faculty point-of-view, the NSU SUMMIT-P leadership team hopes that team-teaching will help create stronger bridges of communication and understanding between various departments as well as foster respect of faculty for one another across departments. As an added bonus, the collaboration has also established research relationships between faculty partners. For example, a mathematics faculty and an engineering faculty, as a result of collaborating as faculty consultants on this project, are now working together on a research project to analyze a differential equations model of the propagation potential in the heart.

Assessments and Surveys

It is imperative that students understand that the application module presentations are supplements to their mathematics learning. Faculty presenters were given the freedom to select their own assessment tools that supported their active learning approach to the presentation. To make sure that students put value in the guest faculty presentations, the syllabi in the targeted

courses specify that students are required to attend guest faculty presentations and to complete assessments prepared by the faculty presenters.

The students were given a short survey at the end of each presentation to gauge the effectiveness of the delivery. The survey did not measure the students' understanding of the content knowledge of the applications. The survey has a Likert-type scale (see Figure 1):

Figure 1

Student's Survey on the Faculty Presentations

	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
1. The presentation provided practical application.					
2. The presentation was informative.					
3. The presentation was interesting.					
4. The information presented help me see how Mathematics is used in Engineering.					
5. Handouts were valuable.					
6. The facilitator provided clear explanations.					
7. The facilitator presented material in an organized fashion.					
8. The facilitator stimulated interest and discussion.					
9. The facilitator was responsive to participants.					
10. The facilitator was effective in style and delivery.					

The students' feedback through this survey was helpful for faculty as they revised their presentations, and their comments were very encouraging in revealing their interests in future engineering classes and engagement in their discipline. In fact, the presentation made by one of the engineering professors in a laboratory session during the Fall 2019 semester helped him recruit a couple of freshmen engineering majors to work in his optical engineering laboratory. Indeed, we were able to achieve one of our goals at NSU—to establish meaningful academic connections for our HBCU students through mathematics.

A Work in Progress

At NSU, we are continuing to seek ways to improve and enhance the interdisciplinary partnerships through SUMMIT-P. As part of the SUMMIT-P consortium, NSU contributes by offering our HBCU students high-quality training that is comparable to what their peers receive in other institutions, increasing awareness of the challenges and issues that students and faculty encounter in an HBCU, and providing an opportunity to form close teaching, learning, and research connections and opportunities between the students and faculty of mathematics and other departments within the College of Science, Engineering and Technology.

What does it take to teach mathematics effectively to students in a public HBCU? We do not have undisputable answers to this important question. But at NSU, the SUMMIT-P leadership team and the faculty consultant teams recognize that providing quality mathematics education to our HBCU students requires multidisciplinary effort. We strive to promote partnership and cultivate colleagueship between departments in the College of Science, Engineering and Technology (CSET). It is our strong belief that perspectives and applications from outside the mathematics classrooms will influence vital changes towards a mathematics curriculum that will provide a solid and an excellent foundation for success in the upper-level courses.

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