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Teaching Undergraduate Calculus at an Urban HBCU through a Global Pandemic

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Abstract

Over the last decade, there has been a national effort to prepare a more diverse student population for success in science, technology, engineering, and mathematics (STEM) careers. While there are a variety of best teaching practices in undergraduate STEM education, student engagement has been widely used to improve student learning. Specifically, it is important for students to have opportunities to practice or apply the theory they have learned in courses to real-world problems. Implementing active learning is one model that can be used to achieve this objective. However, due to the COVID-19 pandemic, professors have had to offer courses in online formats and determine how to continue to implement effective teaching strategies during this unprecedented time. Professors are anticipating the possibility of the need to continue offering courses in fully online and hybrid formats even in the future. With an emphasis on a STEM gateway course sequence, the aim of this paper is to highlight pre-COVID-19 research studies in online STEM education at Historically Black Colleges and Universities (HBCUs), explore how COVID-19 impacted students, teaching, and learning in undergraduate calculus courses, and outline opportunities for continuing to implement teaching techniques that work effectively for in-person and online calculus instruction.

Introduction

Within the last decade, there has been increasingly more emphasis on STEM education from a national perspective (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012). In 2012, the President's Council of Advisors on Science and Technology (PCAST) developed a report on the state of science, technology, engineering, and mathematics (STEM) in the United States of America entitled "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics." This report stressed the importance of increasing the number of graduates in STEM disciplines for America to maintain scientific prominence. Specific challenges that must be addressed in college and university classrooms are identified and three recommendations are outlined in the report as follows: 1) improve the first two years of STEM education in colleges/universities, 2) provide all students with the tools and resources they need to excel, and 3) diversify

pathways to STEM degrees (President's Council of Advisors on Science and Technology, 2012). Enhancing instructional practices in calculus is one approach that can be used to improve the first two years of undergraduate education for students majoring in STEM disciplines and this could have a positive impact on the retention and persistence of STEM students.

Continuing with this national initiative, in 2018 a report entitled "Charting a Course for Success: America's Strategy for STEM Education" was developed by the Committee on STEM Education of the National Science and Technology Council. This report identified a new vision "for a future where all Americans will have lifelong access to high-quality STEM education and the United States will be a global leader in STEM literacy, innovation, and employment" (Committee on STEM Education of the National Science and Technology Council, 2018). Three goals are outlined in the report as follows: 1) build strong foundations for STEM literacy, 2) increase diversity, equity, and inclusion in STEM, and 3) prepare the STEM workforce for the future. Especially at Minority Serving Institutions (MSIs) like Historically Black Colleges and Universities (HBCUs), improved instructional practices in calculus can also lead to an increase in the number of African American students, who have been traditionally underrepresented in STEM, on track to be prepared to enter the STEM workforce in the future.

Traditionally, college classrooms have been a place where professors lecture and students are expected to listen and learn without much participation. Yet, over the last two decades there has been more of a focus on student engagement and a trend toward refashioning the college classroom to promote dynamic student-centered learning. This change is particularly significant for college students in pursuit of degrees in STEM disciplines since the ability to apply the knowledge, skills, and theory learned in the classroom is vital to success in their future careers.

Since calculus is a fundamental course for most STEM areas of study it has the potential either to provide students with a strong foundation for more advanced classes and prepare them with the confidence and skills needed to persist and excel in STEM, or to deter students from continuing in undergraduate STEM programs. As a result, many students leave STEM majors before they can realize their potentials in STEM fields (Petrillo, 2016). However, the teaching techniques implemented by the professor can have a major impact on students' interest, motivation, abilities to access their background knowledge, and their overall academic performance. Therefore, especially amid a global pandemic, it is critical to provide an engaging calculus learning experience.

Moreover, mathematics skills have been recognized as a core competence for students majoring in STEM disciplines, but for some students the mathematics courses can be challenging due to student deficit attitudes or lack of preparedness, but these challenges can be addressed through instructor action (Yang, Fu, Hwang, & Yang, 2017). Since mathematics is at the core of the knowledge and skills necessary for success in STEM disciplines, it has been noted by the Mathematical Association of America (MAA) in its Instructional Practices Guide that undergraduate mathematics courses such as calculus, linear algebra, and differential equations should require proficiency as the primary goal. According to the MAA, measuring student proficiency means that each student is assessed based on a fixed target outcome, regardless of their starting point (Abell, 2018). Specifically, to evaluate student proficiency in courses like calculus and above, it is critical to create a learning environment that

fosters student engagement and supports student learning. Active learning techniques in mathematics is one approach that has been shown to lead students to procedural fluency, strong theoretical understanding, and the ability to excel in calculus (Abell, 2018). Active learning is a method of instruction in which students actively engage with the course material through activities like discussions, problem-solving, and reflective writing.

Calculus, the context in which the study is situated, is a required course for students majoring in most STEM disciplines. At this university, the first calculus course is required for students majoring in biology and chemistry, and the entire calculus sequence is required for students majoring in architectural engineering, civil engineering, computer science, electrical engineering, mathematics, and mechanical engineering. Since calculus is a gateway course for undergraduate students majoring in these STEM disciplines, success in this course is imperative to the ability of these students to persist and excel in their academic majors.

In the last couple of years, the outbreak of COVID-19 became a major disruption to colleges and universities across the United States of America. Midway through the spring 2020 semester the coronavirus caused most institutions to cancel face-to-face classes and move to online-only instruction. In fact, during this time more than 1,300 colleges and universities in all 50 states canceled face-to-face classes or transitioned to online-only instruction (Smalley, 2021). Consequently, this shift to online-only classes raised concerns about the quality of educational instruction provided remotely. The president of Tennessee State University, the home institution of this research study, began issuing university-wide COVID-19 updates on March 5, 2020, and within one week, the decision had been made to transition to online classes. This pronouncement was promptly followed by the decision to shift most university operations to remote formats. These and each decision that followed were in response to the rapidly evolving crisis, COVID-19, and made in accordance with existing local, state, and national guidelines.

Prior to the COVID-19 pandemic, literature was available that highlighted the importance of broadening participation in STEM fields. To ensure our nation's continued progress and advancement scientifically and technologically, supporting undergraduate student success in STEM fields is vital (Espinosa, 2011). Yet, there are not enough people from diverse populations, including women, participating in STEM disciplines. Therefore, for the United States to remain competitive in STEM, it is imperative to create learning opportunities and pathways for all students, including underrepresented minorities (URMs), who are interested and capable of pursuing STEM degrees and becoming STEM professionals. Specifically, the need to broaden participation in STEM is important for those who identify as African American or Black. In that regard, HBCUs may have a unique advantage in the nation's efforts to significantly increase the participation of African Americans in STEM fields (Upton and Tanenbaum, 2014).

Although HBCUs make up only three percent of American institutions of higher education, HBCUs award twenty-seven percent of the STEM bachelor's degrees conferred to African Americans (Glenn Jones & Davenport, 2018). Therefore, HBCUs occupy a distinctive space in American higher education, particularly in their ability to increase pathways to STEM. To achieve this potential, it is imperative for STEM professors at HBCUs to create classroom environments that promote positive learning experiences.

Even with the potential which lies within the constructs of HBCUs, the COVID-19 pandemic became a great disruptor to meeting this goal; yet the pandemic also propelled us toward new opportunities to redesign courses for improved learning using all formats (in-person, hybrid, and fully online). The ongoing coronavirus pandemic has created an unparalleled crisis that has had global consequences. Educators at all levels were challenged with maintaining relationships and ensuring quality while balancing student academic needs with their own personal safety and for some monitoring their own children's online educational progress (Kruse, Hackmann, & Clark Lindle, 2020). The pandemic has also caused leaders at academic institutions to restructure systems, determine and implement strategies to enhance the ability of faculty and students to function at high levels online/remotely, and ensure instructional quality even in fully online settings while operating with diminished resources. The transition to digital learning is just one example of a significant and immediate response that was a consequence of the global pandemic and has affected students, educational institutions, programs, faculty, and staff who lead these institutions (Kruse, Hackmann, & Clark Lindle, 2020).

This research, which involved URM students majoring in STEM disciplines, can help meet the goals of both the PCAST report and the recent report developed by the Committee on STEM Education of the National Science and Technology Council. With a focus on pedagogical methods and student perspectives in undergraduate calculus at an urban HBCU during the COVID-19 pandemic, students majoring in STEM disciplines were the focal point of this research study. The findings of this research have the potential to impact the body of knowledge on best practices in teaching and learning for URM students in STEM, expand the body of work focused on effective teaching strategies in online undergraduate mathematics courses, and broaden the published work on online teaching and learning in STEM disciplines at HBCUs.

Online Learning in STEM Courses at HBCUs Pre- COVID-19

Since the 1990s online education has grown and this has given colleges and universities a way to expand their reach to more students. Although there has been an increase in online courses and program offerings across disciplines, there is still a lack when it comes to online courses and programs in STEM disciplines especially at HBCUs. In thinking about re-envisioning undergraduate STEM education in the wake of COVID-19, it was important to consider online learning in STEM courses at HBCUs prior to the pandemic. Since 2010 there has been a slight increase in online distance education courses in STEM disciplines at HBCUs, but there is a lack of literature on online teaching and learning in undergraduate STEM courses at HBCUs. The research studies conducted prior to the pandemic examined student self-motivation, student commitment to their learning, student self-efficacy, course design, and faculty support and preparation, to assess the effectiveness of distance education in STEM disciplines at HBCUs.

Learning at a distance typically requires a greater degree of self-motivation and a commitment from the student. In fact, the Institute for Higher Education Policy lists these and the need for setting specific expectations among its course structure benchmarks for ensuring quality in online distance education. The course structure benchmarks include four main components: 1) Before starting an online program, students are advised about the program to determine if they possess the self-motivation and commitment to learn at a distance and if they have access to the

minimal technology required by the course design. 2) Students are given supplemental course information that outlines the course objectives and concepts/ideas and learning outcomes for each course are clearly summarized. 3) Students have access to enough library resources which may include a "virtual library" available online. 4) Faculty and students agree upon expectations regarding times for submitting assignments and faculty response (Merisotis & Phipps, 2000).

Davidson and Beck (2007) define structure dependence as providing clear, detailed guidelines for academic assignments, but this article did not discuss online learning. However, researchers in a 2010 study used the Structure Dependence scale to identify components of online courses that students consider to be a positive influence on their academic performance and found that students in online science and engineering courses at an HBCU tended to prefer instructional environments that had more structure than students who took traditional courses (Flowers et al., 2010). Due to the complexity of STEM courses and the challenges faced by students learning on a largely individual basis, the researchers suggest that academic performance may be directly linked to students' needs for the integration of structure in the framework of online courses (Flowers et al., 2010).

Another research study was conducted which focused on the self-efficacy of students in biology and computer science courses at an HBCU using The Survey of Academic Orientations academic self-efficacy subscale and participants included students in online and traditional courses. Multiple regression analysis was done on the collected data and the results of the study suggest that online STEM HBCU students' self-efficacy may be similar to that of STEM HBCU students taking face-to-face courses. Using evidence-based implications for enhancing online pedagogical practices to improve online student self-efficacy, the researcher outlines several strategies to effectively design and implement online STEM courses including rubrics for all assignments, well-designed discussion posts, and collaborative assignments, and administering surveys to the students about educational technology skills, learning styles, study skills, collaboration skills, time-management skills, number of previous STEM courses, number of previous online courses, and communication skills as formative and summative assessments in order to improve instruction (Flowers, 2011).

A 2012 study was conducted to examine African American students' participation in online distance education and highlights the need for HBCUs to further develop distance education in STEM disciplines and other areas to increase their academic competitiveness and sustainability. Utilizing descriptive data from the National Center for Education Statistics, the HBCU Distance Learning 2010 report, and the National Postsecondary Student Aid Study, the researchers identified significant differences in the percentage distribution of student participation in distance education by race and the percentage distribution of African American students' participation in distance education noting the following: 1) 10.8% of STEM majors were enrolled in distance education courses while 78.1% of non-STEM majors were enrolled in distance education courses, 2) during the survey period 83% of college students taking online courses were White and 17% of college students taking online courses were African American, and 3) 18% of the 105 HBCUs possess online degree programs (Flowers et. al., 2012). The researcher also suggests several ways HBCUs can develop sustainable online courses and program offerings, which include the following: faculty development, technology enhancements, and procedures for effective formative and summative assessments for online courses and programs (Flowers et. al., 2012).

The results of a 2014 study to examine the effects of online distance education on the perceived learning gains of African American students in science courses at an HBCU showed that students taking traditional science courses self-reported greater affective and psychomotor learning gains than did students taking online distance education science courses (Flower et al., 2014). The researchers grounded their work in equivalency theory which asserts that distance education courses must be designed using similar curriculum development strategies as used in traditional courses. Ordinary least squares regression was used to determine the extent to which online distance education science courses and traditional science courses resulted in equivalent perceived student learning outcomes. Significant negative direct effects were yielded on the affective and psychomotor subscales of the Cognitive, Affective, and Psychomotor Perceived Learning Scale (Flowers et al., 2014). The researchers suggest that the learning experiences of the online distance education courses may not have been equivalent to those of the traditional courses. They believe that there would have been no significant differences in perceived affective and psychomotor learning gains if equivalency learning theory had been utilized to design the online distance courses. This study, while emphasizing student outcomes in individual courses, does not report on programmatic outcomes, which has been a criticism of research on distance education (Berge & Mrozowski, 2009). The significance of this study is its expansion of the limited literature on distance education in STEM courses at an HBCU.

A 2017 study reported on the impact of a quality-assurance process training on online education course design and the application of the quality course design standards on student outcomes for faculty teaching introductory mathematics and science courses at an HBCU (Hollowell et al., 2017). In a comparison of post-training and pre-training data, the researchers found significant increases in faculty's knowledge of online teaching and in students' final exam scores and overall course averages. Further, the data showed a correlation between faculty quality assurance training review scores and student final exam scores (Hollowell et al., 2017). The faculty participating in this study were in a STEM faculty learning community that was focused on the redesign of their online courses based on best practices. The researchers believe that the use of faculty learning communities may be an effective strategy to increase the quality of online STEM courses (Hollowell et al., 2017). This study adds to the body of research on distance education in STEM courses at HBCUs by reporting on student outcomes and instructor training, which is one of the faculty support benchmarks established by the Institute for Higher Education Policy to ensure quality in online distance education (Merisotis & Phipps, 2000).

The purpose of this literature review was to provide a summary of research published on distance education in STEM disciplines at HBCUs prior to the COVID-19 pandemic. The articles presented here reported on research that examined student outcomes, student perceptions, and student satisfaction using descriptive or correlation research to determine the effectiveness of distance education in STEM disciplines at HBCUs prior to the COVID-19 pandemic. Based on this literature review it seems there is a strong link between metacognitive/affective constructs (self-efficacy, self-motivation, and commitment) and course design. With the proper training faculty can better design courses, which can lead to more sustainable online courses that positively impact student learning. The research published in this area is limited and many of the researchers spanned multiple research teams. This is evidence of the fact that there is a need for more original investigations that explore best practices in the implementation of distance education in STEM courses and programs at HBCUs and the phenomena related

to those implementations. Especially due to the recent pandemic, the articles in this review serve as precursors of the sustained research that is needed to expand the body of knowledge in this area.

Online Learning through a Global Pandemic

To prevent the spread of COVID-19, face-to-face classes were suddenly transitioned to online formats, which caused an immediate change in teaching and learning modalities. This caused professors and students to quickly try to determine how to best navigate this unexpected situation, professors were tasked with implementing high-quality distance education that maintained high levels of student engagement. In terms of best practices for undergraduate STEM education for HBCU students, now in the wake of COVID-19, professors have been prompted to explore and implement new ideas and strategies to support student success.

To gain more insights about student and faculty perspectives during COVID-19, the researchers of this study searched for articles which captured data on higher education experiences during the pandemic. A research study sponsored by Digital Promise Accelerating Innovation in Education, Every Learner Everywhere, and Tyton Partners was conducted to learn more about how the experiences of the faculty and students compared to others around the United States. The results were presented in two national surveys entitled, "Suddenly Online: A National of Undergraduates during the COVID-19 Pandemic" and "Time for Class: COVID-19 Edition Part 1: A National Survey of Faculty During COVID-19", the focal point here is the student perceptions and experiences during this situation. Out of 1,008 undergraduate students surveyed, 717 students were attending 4-year colleges or universities that transitioned face-to-face courses to remote learning during the spring 2020 semester (Fox, et. al, 2020).

The student survey participants' responses varied in terms of subject area, therefore, only sixty-three percent responded based on a STEM course. The most common subjects for the STEM courses were biology (eleven percent), mathematics (ten percent), computer science or technology (eight percent), engineering or engineering technology (eight percent), chemistry (seven percent), health profession (seven percent), business (five percent), and accounting (five percent) (Means and Neisler, 2020). Fifty-six percent of students, the majority of the student respondents, reported having thirty-five or fewer students in their courses, and sixty-seven percent of all student respondents reported having synchronous classes, which is consistent with the size of the classes and the type of online instruction offered in the calculus courses which are the focus of this research study. When student participants were surveyed about comparing their experiences before and after the shift to remote instruction, in terms of understanding the course expectations over half of the students indicated that it was about the same. When student participants were surveyed about opportunities to collaborate with other students on course work, over half of the students indicated that it was worse online (Means and Neisler, 2020). This suggests that most students believed that professors were clear about their expectations regardless of the teaching format, and most students believed it was more difficult to collaborate with other students in an online course.

More than 4,000 faculty at over 1,500 from 2-year and 4-year institutions across the nation participated in the survey with data presented in a disaggregated format. Many of these faculty thoughtfully transitioned instructional

strategies and implemented new teaching tools and 75% of these faculty used a combination of synchronous and asynchronous teaching techniques (Fox, et. al., 2020). Yet, the top three challenges for faculty respondents were keeping students engaged at 60%, providing additional support for students at 30%, and administering secure tests at 29%, which were challenges faced by the faculty involved in the research study presented in this paper. These surveys addressed several aspects of online teaching and learning, which took place because of the unanticipated pandemic. Aligned with many of the areas of focus in these national surveys, this research study surveys STEM students at an urban HBCU to understand their experiences, perspectives, and academic performance in mathematics in the wake of COVID-19.

Background

The university which is the focus of this paper is a comprehensive, urban, coeducational, land grant university, and an HBCU that was founded in 1912. This university is the only public institution of higher education in its city and is designated as an R2 Doctoral Institution with high research activity and offers associates, bachelors, masters, and doctoral degrees. The current enrollment is 6,000 undergraduate students of which 81% are African Americans.

At this university, there are three courses in the calculus sequence: Calculus I, Calculus II, and Calculus III. The first calculus course is required for students majoring in biology and chemistry, and the entire calculus sequence is required for students majoring in architectural engineering, civil engineering, computer science, electrical engineering, mathematics, and mechanical engineering. Typically, each calculus class meets for 55 minutes, four days per week for a total of 14 weeks. Successful completion in calculus means that a student earned an A, B, or C in the course. Failure means that a student has earned a D, F, or W in the course, where W represents withdrawal.

At the university, which is the focus of this research study, traditionally calculus had been taught using lecture as the main technique for instruction. However, with the goal of improving student success in mathematics courses in recent years, some faculty have incorporated other teaching techniques and technologies to create a more engaging learning environment. The strategic engagement for increased learning (SEIL) model was created to enhance student learning by elevating their level of preparedness for, confidence, and interest in learning calculus through developed classroom engagement (Stanberry, 2018). Implemented by faculty who participated in this research study, the SEIL model includes active learning techniques and the use of technology like student response systems, an online education platform, and an online learning management system. Even during the global pandemic, the faculty involved in this research study strived to continue to implement some of the teaching strategies, techniques, and activities that were successful in face-to-face classes.

This paper aims to identify potential opportunities for innovation in STEM education and to explore the impact of COVID-19 on teaching calculus to undergraduate students at an urban HBCU. One goal of this paper is to contribute to the body of knowledge on how to enhance undergraduate STEM education through an improved understanding of online teaching and learning.

Definitions

Definitions and descriptions of key terminology utilized in this research study are outlined in this section. Multiple means of engagement is a method used to involve students in the learning experience in a variety of ways, for example, homework, classwork, group work, reflections, quizzes, tests, and presentations. Structured assignments refer to assignments like online homework and reflections. Classwork assignments were done during class time in groups in breakout rooms and included short assignments to practice concepts previously covered. Reflections were written assignments designed to encourage students to plan for their success in the course, reflect on specific topics learned in the course including those for which it was challenging to learn, and consider related topics they are curious to learn about. This assignment allowed students to share their opinions/perspectives about their learning, build their science and mathematics writing skills, and further develop their mathematical communication skills. Reviewing student reflections was an opportunity for the faculty to get to know the students better in terms of their academic goals/interests and receive feedback about student progress in terms of learning the course content. Discussions occurred during class time, especially when group classwork was assigned to heighten the students' understanding of topics covered in the course. Collaborative and peer learning was a part of many different assignments to create a community of learners and provide support for student learning through faculty and student interactions. Group problems were assigned to build community in the classroom, give students an opportunity to work together and learn from each other, increase the students level of understanding of topics covered in class, help students develop their ability to utilize technology to communicate mathematics by completing video presentations in which they verbally and visually demonstrated their knowledge by applying theory learned in class to real-world problems. During the semesters which are a part of this research study, d2L/eLearn was the online learning management system used to communicate with students and share course materials, like the syllabus which included a detailed course calendar with the grading policy, synchronous class sessions were held using the video conferencing platform called Zoom, homework and quizzes were done in the online education system called WebAssign, and students were given assignments to be done outside of synchronous class meeting times individually and in groups. Rubrics specifying the criteria by which the assignments would be assessed were used for reflections and group problems so that students would be clear about how these assignments would be evaluated.

Method

This is descriptive research, and it is intended to lay the groundwork for future research studies in online teaching and learning in STEM disciplines at HBCUs. Based on this research study, which was conducted during a global pandemic, the following research questions are addressed: 1) What are students' attitudes and beliefs about their experiences taking calculus online? 2) Do students' self-efficacy align with their academic performance in an online calculus course?

The focal population for this research study is students enrolled in calculus courses taught by participating faculty. Students who were enrolled in sections of Calculus I, Calculus II, or Calculus III during spring 2020, fall 2020, and spring 2021 were recruited to participate in this research study. For the purposes of this research study, the

data collected during the spring 2020 semester were exempted due to the abrupt transition to remote learning at the midterm of the semester. This study includes semesters during which the students were enrolled in calculus courses which were taught online for the full term. The research study sections from the fall 2020 and spring 2021 sections included 122 students enrolled in Calculus I, 26 students enrolled in Calculus II, and 59 students enrolled in Calculus III. Final grade data were collected for all students, and survey responses were collected from students who consented to have their responses included in this research study. Since there is a lack of research focused on online learning in STEM courses at HBCUs, there were no pre-existing surveys relevant to the focus of this study available for comparison purposes. Therefore, the researchers developed the survey questions based on their experiences and expertise in the field, and they were confident that student responses to these questions would offer insight into student learning experiences and techniques and tools that work best in online undergraduate calculus courses.

The faculty engaged in this research study successfully completed the university eLearn training course and had previous experience with WebAssign and Zoom. The calculus courses that were a part of this research study included synchronous meetings three days per week via live Zoom sessions and asynchronous readings and assignments for each week of the semester. The faculty used eLearn to post the details of course expectations, the grading policy, the course calendar with the dates and times for all class meetings and assignments, and details about how to submit assignments. Also available in eLearn were the Dropbox, gradebook, and group management tools. The faculty used WebAssign to develop online homework and quizzes, and Cengage, the publisher of WebAssign products, was used by the faculty for additional instructor resources. Zoom was critical for synchronous class meetings and features such as breakout rooms and polls were utilized. Additionally, the Zoom platform provides tools such as chats for answering and responding to questions, raising hands, and a plethora of other features which were also useful in the teaching and learning process. Both WebAssign and Zoom were integrated into eLearn to allow for easy accessibility for the students. According to existing literature, there are eight instructional practices that have been identified as contributing to more effective online teaching and learning: assignments checking what students know and what they still need to learn, interactive lecture, frequent quizzes or other assessments, live class discussions, meeting in breakout groups, personal messages to students about their academic progress and access to course materials, using real-world examples to illustrate course content, and group project assignments (Means & Neisler, 2020). This research study utilized all these instructional practices.

Based on the survey data collected in Time for Class – COVID-19 Edition Part 3: The Impact of 2020 on Introductory Faculty and their Students, faculty made major changes to introductory-level courses taught during the fall 2020 semester. For instance, 72% of instructors integrated new digital tools; 70% of instructors updated learning objectives, assessments, and activities; 60% embedded active learning components; and 46% of the instructors increased the frequency of assessments to track student learning more closely (Fox, et. al., 2021). Consistent with these results, the faculty engaged in this research study implemented assignments and assessments that they believed would keep students actively involved in the class and connected to the course content, other students, and the professor of the course. Many of these activities were implemented to mirror some of the activities and strategies typically done for face-to-face calculus classes and included multiple means of

engagement and frequent student knowledge checks because the faculty involved in this research believed this was important for student success. The faculty maintained online homework, classwork, online quizzes, in-class tests, and an in-class final exam. However, reflections and group problems were added as grade categories.

Even in teaching calculus online, the faculty engaged in this research study continued to implement active learning techniques. Specifically, journaling, discussions, and collaborative learning/peer learning were utilized. It was the hope of the faculty involved in this research project that these assignments would help students with achieving their course goals, enhancing their critical thinking skills, and improving their ability to communicate mathematics.

Results

A five-question survey that included Likert-styled prompts was administered to student participants to collect information about their beliefs and attitudes in three different areas: online learning, instructional practices, and confidence. These were all categories that the faculty involved in this research study believed were important to understanding effective teaching practices and how students learn best in an online classroom environment, specifically for undergraduate calculus courses. This survey also collected data about the majors of the students; this information is showcased in Figure 1.

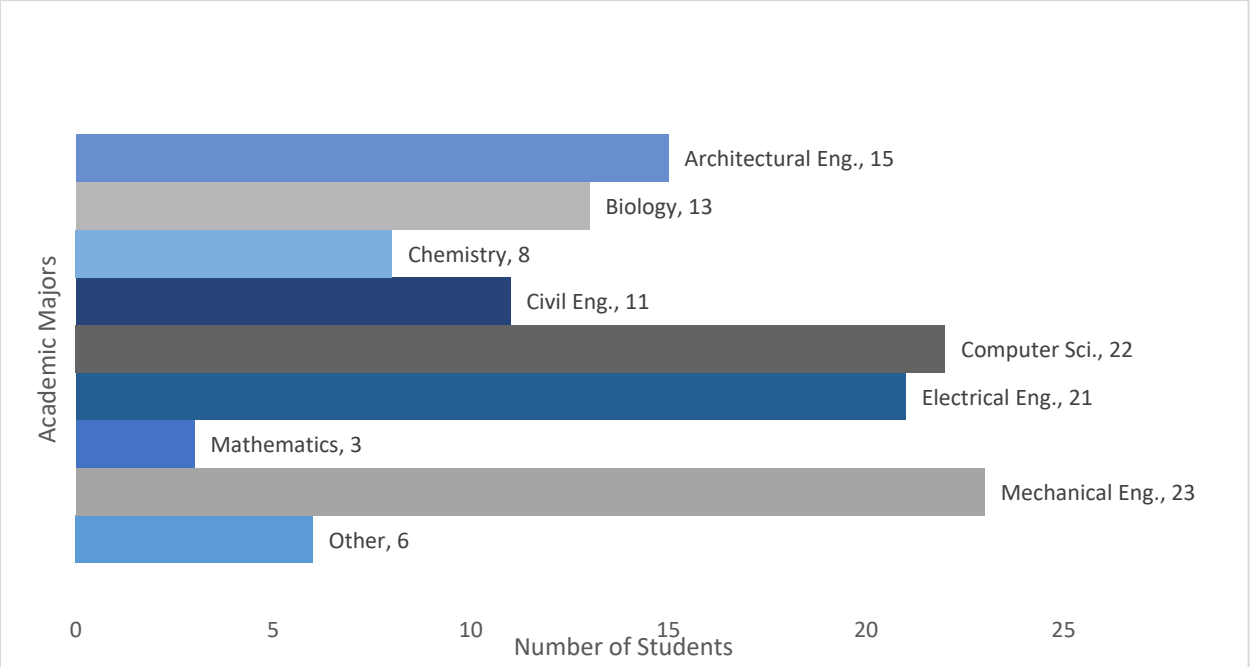

Figure 1. Number of Students Enrolled in Calculus Courses by Major Academic Year 2020-2021

Table 1 shows the results of students' attitudes about online learning. At 66.7%, most of the students strongly agreed or agreed to a preference for face-to-face courses. At 74.8%, an even higher percentage of the students strongly agreed or agreed with a belief that professors explained the course content better in face-to-face classes than in online classes. However, only 39% of the students strongly agreed or agreed that they spent more time

preparing for online classes than face-to-face classes. The results of these data suggest that many of the students who were enrolled in online calculus courses during the pandemic may not have selected this type of learning format prior to the transition to remote learning and that they may not have been fully acquainted with the responsibilities of the student in an online learning environment. Also, in online courses, the professor does not have the ability to gauge the students' level of understanding by seeing their facial expressions, and the professor does not have the option to walk around the classroom to assist students one-on-one during class time. Therefore, certain interventions and instructional support that could be done in face-to-face courses are not always possible in online courses.

Table 1. Students' Attitudes about Online Learning

Prompts	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
I prefer to take courses face-to-face.	49.6%	17.1%	21.9%	5.7%	5.7%
I spend more time preparing for online classes than face-to-face classes.	23.6%	15.4%	24.4%	27.6%	8.9%
I believe that professors explain course content better in face-to-face classes than in online classes.	52.0%	22.8%	16.3%	4.9%	4.1%

Table 2 shows the results of students' responses when surveyed about instructional practices. An overwhelming majority of the students strongly agreed or agreed that the multiple means of engagement increased their knowledge and comprehension of course content and that structured assignments increased their knowledge and comprehension of course content at 82.9% and 84.6%, respectively. However, only 46.4% of the students indicated that they strongly agreed or agreed that they enjoyed collaborating with other students and doing group work. One factor that could explain why this percentage is not higher is that the students may prefer working on collaborative assignments in a face-to-face environment just as they seem to prefer learning in a face-to-face environment.

Table 2. Students' Beliefs about Instructional Practices

Prompts	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
I enjoy collaborating with other students and doing group work.	17.9%	28.5%	22.8%	20.3%	10.6%
I believe that multiple means of engagement increase my knowledge and comprehension of the content covered in this class.	33.3%	49.6%	13.8%	3.3%	0.0%
I believe that the structured assignments help increase my knowledge and comprehension of content covered in this class.	40.7%	43.9%	9.8%	4.9%	0.8%

Table 3 shows students' responses when surveyed about confidence in mathematics. When students were surveyed about their confidence in the online calculus course, most students, 66.7%, strongly agreed or agreed that they were confident in their own mathematical ability and 80.5% strongly agreed or agreed that they believed the knowledge and skills they learned in the calculus course would help them in their future courses. This indicated that students believed they could excel in calculus and from their perspective and there was value in taking the course because they could see the relevance of the course content to their future academic work.

Table 3. Students' Confidence in Mathematics

Prompts	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
I am confident in my mathematical ability.	18.7%	48.0%	27.6%	5.7%	0.0%
I believe the knowledge and skills that I learn in this course will help me in my future courses.	41.5%	39.0%	15.4%	4.1%	0.0%

Other course data, like the grade data for each course, were also collected. What follows in Table 4 and Table 5 is the grade distribution for the sections of Calculus I, Calculus II, and Calculus III, in which this research study was conducted. There were five sections of Calculus I, one section of Calculus II, and two sections of Calculus III included in the research study. The course, the percentage of students who earned each grade, and the total number of students who were enrolled in each course are displayed in Table 4 for fall 2020 and Table 5 for spring 2021.

Table 4. Fall 2020 Calculus Final Grades

Course	**A**	**B**	**C**	**D**	**F**	**W**
Calculus I (*n=66*)	18.2%	24.2%	31.8%	9.1%	16.7%	0.0%
Calculus II (*n=26*)	15.4%	42.3%	23.1%	7.7%	11.5%	0.0%
Calculus III (*n=26*)	19.2%	30.8%	19.2%	11.5%	19.2%	0.0%

Table 5. Spring 2021 Calculus Final Grades

Course	**A**	**B**	**C**	**D**	**F**	**W**
Calculus I (*n=56*)	7.1%	35.7%	32.1%	10.7%	14.3%	0.0%
Calculus III (*n=33*)	27.3%	18.2%	33.3%	9.1%	9.1%	3.0%

In examining the grade data, the researchers determined the success rate in each of the research study sections by calculating the percentage of students who earned an A, B, or C in the course. The following is the success rate for each section during the fall 2020 semester: Calculus I was 74.2%, Calculus II was 80.8%, and Calculus III was 69.2%. The following is the success rate for each section during the spring 2021 semester: Calculus I was 74.9%, and Calculus III was 78.8%. In an online learning environment, students' self-efficacy can be influenced by factors such as their ability to navigate the online learning platform and their confidence in their ability to learn

in an online environment. Based on the final grade data, the students' self-efficacy data found in Table 3 do align with their academic performance in these online calculus courses.

In addition to the proposed research questions for this study, the faculty also wanted to understand the students' perspectives on the impact of the pandemic on their learning. In an anonymous survey, the faculty posed the question: Has the COVID-19 pandemic impacted you in regard to learning calculus? A variety of responses from the students was yielded by this question. The comments provided insight that can be integral to the online learning environment beyond the COVID-19 pandemic. The most common comments are highlighted below:

- "I prefer in-person classes to focus and engage better."
- "It is slightly harder to grasp the concepts and it is also harder to ask specific questions or to even know what questions to ask."
- "I feel as though mathematics is a course that should be taught in class rather than online because you are more engaged rather than looking at the same computer screen every day. Attending class gives you something to look forward to, and it improves your motivation to study and retain the content."
- "I feel disconnected from my work and classmates to a certain extent by being a remote student."
- "Interaction with my professor would improve my comprehension of the material."
- "No, calculus has been a consistent course because we are constantly engaging by working examples."

Implications

In a constantly changing, increasingly complex world, it is important for our nation's students to gain knowledge and skills necessary to solve problems that require collecting, interpreting, analyzing, and evaluating information to make sound decisions, which are the types of skills that students develop in STEM courses (U.S. Department of Education, 2019). As a result, there has been a focus on STEM education from a national viewpoint. To address these national STEM initiatives, particularly in terms of enhancing diversity, inclusion, and diversifying pathways to STEM degrees, HBCUs have a unique opportunity to help the nation in increasing the number of URMs with STEM degrees and in building a stronger STEM workforce. This number could increase if more students have access to enroll in STEM courses offered through a variety of modes (face-to-face, hybrid, and fully online).

For HBCUs to offer more access to diverse students, specifically to address the goals outlined in the national reports, more undergraduate online courses and online programs are necessary for STEM areas. Moreover, following the coronavirus pandemic, it is important to have the means to offer all types of undergraduate courses via distance learning, including STEM courses. This pandemic has resulted in heightened discussions among professors and university administrators about distance learning and its importance in higher education.

This increased exposure and experiences with online teaching and learning have positively impacted faculty perceptions of instruction in online courses and has prompted lasting changes to teaching and learning (Fox, et. al., 2021). During the pandemic, faculty had opportunities to try new and effective teaching techniques and tools, which have the potential to enhance even face-to-face classes. STEM faculty are now tasked with determining how to adapt face-to-face instruction to include the utilization of technology tools and teaching strategies that

were successful in online instruction. Furthermore, in transitioning back to teaching face-to-face courses STEM faculty and other academic decision-makers could consider the question: What is the best way to design STEM courses, implement effective teaching techniques, and use technology tools which will maximize student learning and academic performance?

The pre-COVID-19 literature on STEM online teaching and learning at HBCUs focused on topics such as student self-motivation, student commitment to their learning, course structure and rubrics, student self-efficacy, and faculty support and preparation. This research study highlighted student experiences, perspectives, and self-efficacy in online calculus courses during a global pandemic as well as the active learning techniques implemented into these courses. Based on the anonymous student feedback related to their perspectives in the research study courses, it seems that certain activities enhance the students learning experiences. For instance: specific questions can be posed and discussed by using the poll question feature in Zoom or clicker technology, and students can be grouped using the breakout room feature in Zoom so that the professor can spend quality with the students in smaller groups to clarify course content.

Future Research

The proliferation of online education in the higher education arena has resulted in many "how to" papers, policy papers, and research papers concerning its impact on the educational effectiveness of colleges and universities. However, there continues to be a dearth of original research on online education in STEM disciplines at HBCUs. An emerging body of work from a research team focused on online education in STEM courses and programs at an HBCU has begun to chart a path for continued explorations in this area.

As a result of the COVID-19 pandemic and the need for colleges and universities to abruptly change and unexpectedly offer all courses remotely, it prompted more professors to reimagine undergraduate STEM education and take action to do something different in terms of the way their courses are designed and taught. As the body of work on online teaching and learning in undergraduate STEM education expands, future research should explore the impact of innovative teaching technologies on students, including URMs. Moreover, it is important for professors at all types of institutions to search for new ways to engage all students and enhance the learning environment to reach learners with a variety of learning styles even in remote settings. If professors find ways to engage students even those traditionally underrepresented in STEM, then these students are more likely to excel and persist in STEM courses.

Aligned with national STEM initiatives, online learning in higher education challenges professors to be more creative and innovative in delivering high-quality STEM education. The type of online learning that has been required in higher education due to the coronavirus pandemic may influence the future of online learning through using more video-conferencing to simulate face-to-face environments, increasing the types of learning opportunities available to students, and varying assessments. To highlight the significance of calculus as a gateway course for students majoring in STEM disciplines at this university and the importance of this HBCU contributing to increasing the number of URMs with degrees in STEM this research study explored some of the factors that

impacted student learning in online calculus courses, such as instructional practices, student perspectives about learning calculus, and student confidence.

There are several open questions related to online teaching and learning in undergraduate STEM courses at HBCUs. Future research in this area should include how to optimize the use of technology in STEM courses, how online teaching impacts the integrity of higher education, how to effectively design and implement assessment remotely, how taking an online STEM prerequisite course affects performance in subsequent STEM courses, how online learning impacts student engagement, and how access to online courses and programs impacts student persistence and graduation rates in STEM majors.

Overall, broadening the body of knowledge on STEM online teaching and learning in higher education, specifically with URMs, will lead to increased diversity in STEM and contribute to diversifying pathways to STEM careers. In the wake of the COVID-19 pandemic, online course offerings will increase in undergraduate STEM programs at HBCUs. Further explorations of student self-efficacy are warranted to examine factors that could be mitigated through enhanced instructional practices.

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