

Earlier Access to Cutting-Edge Research Experience for Undergraduate STEM Education at Jackson State University

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The Impact of Introductory-level Course-based Undergraduate Research Experiences on Students' Selection in STEM Majors at Jackson State University

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Abstract—To prepare undergraduate students for success in STEM, this study aims to offer freshmen cutting-edge course-based undergraduate research experiences (CUREs) in a Historically Black University. It has been concluded that the research experience can promote students' interest and retention rate in STEM. This study focuses on developing introductory-level CUREs (I-CUREs). Through lectures and lab tours, I-CUREs introduce students to cutting-edge technologies in STEM disciplines. As students move through their first two years of college, this model will have a significant impact on their educational and career trajectories. It could also help African American students become more engaged in STEM learning and make research accessible to a more diverse group. In this study, the introduction-level lecture was given to freshmen as part of the UNIV 100 Student Success class. Data was collected during the first academic year before and after the I-CUREs course implementation at Jackson State University. Research projects related to a range of cutting-edge technologies including advanced ground improvement and 3D printing technology. Meanwhile, the I-CUREs model has also been incorporated into the Mississippi Summer Transportation Institute, which is part of the Department of Civil and Environmental Engineering's K-12 program. The I-CUREs provided an opportunity for high school students to be exposed to sophisticated, high-tech modern instrumentation, which could in turn stimulate their interest in pursuing science and engineering careers.

Keywords—Course based undergraduate research experiences, major selection, undergraduate.

I. INTRODUCTION

Historically Black Colleges and Universities (HBCUs) play a vital role in American higher education, especially in the STEM majors. These institutions account for only 3% of American colleges and universities but produce more than 20% of African American engineers and scientists [1]. Freeman et al. reported that less than 40% of American students who enter university with an interest in STEM and approximately 20% of STEM-interested underrepresented minority students eventually complete a STEM degree [2]. Meanwhile, HBCUs

award approximately 11% of African Americans with master's and doctoral degrees [3]. However, the proportion of black students receiving higher education in STEM fields is still relatively low. Therefore, motivating African American students to choose degrees in STEM majors is essential to the development of HBCUs.

This study is part of an NSF project in progress, "Earlier Access to Cutting-Edge Research Experience for undergraduate STEM Education at Jackson State University" and it aims to include cutting edge course-based undergraduate research experiences (CUREs) for undergraduate students so they can succeed in STEM. Three models of CUREs will be developed in this project to engage students in addressing common and diverse research questions, including 1) Introductory-level CUREs (I-CUREs), 2) Transitional-level CUREs (T-CUREs), and 3) Upper-level CUREs (U-CUREs). The detailed design of CUREs is shown in Figure 1.

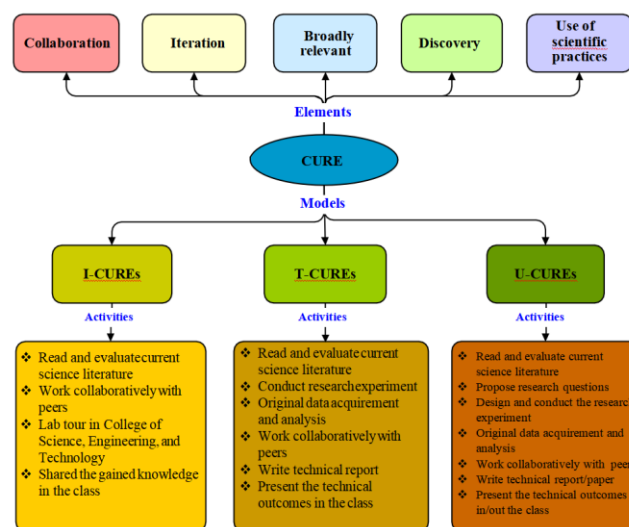


Figure 1. Three different models of CUREs developed in the NSF project and corresponding activities to each model.

This article focuses on the introductory-level CUREs (I-CUREs) part of this project. The I-CUREs model will provide students with a foundational understanding of STEM degrees through lecture classes, lab tours, etc., including the curriculum, cutting-edge technologies, and potential career paths. Researchers found that introductory-level CUREs can increase the student retention rate within the STEM field [4][5][6]. This "experiential" academic guidance class model can exert greater influence on students' educational and career trajectories in the first two years in their college life. In recent years, though with an increase in the total enrollment, only about 10% (Table 1.) of juniors choose to declare STEM as their major in Jackson State University (JSU), and the retention rate for first-time and full-time freshmen in the STEM college is around 80% (JSU data). Therefore, this project is aimed to explore a targeted and effective academic guidance model: I- CUREs to increase the enrollment and retention rate of STEM college. During the year 1 of this project, the I-CUREs model was piloted in the Department of Civil and Environmental Engineering (CEE). And if this program has a good result in the Department of CEE, it can be carried out jointly with other majors in the future.

TABLE I. The percentage of African American students in JSU

	STEM in all majors	African Americans in STEM			African Americans in Engineering		
		B.S Degree	M.S. Degree	Ph.D. Degree	B.S Degree	M.S. Degree	Ph.D. Degree
2017	10%	92%	74%	75%	58%	50%	33%
2018	9%	93%	83%	35%	85%	77%	0%
2019	9%	84%	59%	38%	71%	57%	0%

II. METHODS

A. Participants

This study is aimed at introducing undergraduate and high school students to STEM majors, especially Civil and Environmental Engineering we are piloting, and encouraging them to choose our major or a STEM-related major. Thus, high school students and freshmen are the participants in this study. Since 2022 spring to date, 98 students have participated in the program in succession. Among them, 23 are high school students and 75 are freshmen.

The freshmen were drawn among those who had taken the course that semester on UNIV 100 Student Success. UNIV 100 Students Success is a required general education course, so choosing this course would be easier for us to reach as many freshmen as possible.

The high school students came from the Mississippi Summer Transportation Institute(MSTI). For the last ten years, JSU has offered the MSTI through a Mississippi Department of Transportation (MDOT)/Federal Highway Administration (FHWA) grant on campus to expose minority high school students to Civil/Transportation Engineering subjects. As pre-college students, they are suitable candidates to participate in the I-CUREs program to increase their knowledge about STEM courses and plan for their future careers.

B. Materials

1) Questionnaire

In order to examine whether I-CUREs have an impact on students' interests in CEE, two questionnaires were designed and tested before and after program implementation.

Since the spring of 2022, we have made appropriate adjustments to the questionnaires after each data collection to make them better suited to our study. The first version of the questionnaire contained 16 questions in the pre-test, including 15 multiple-choice questions and one short-answer question, and 14 questions in the post-test, including 13 multiple-choice questions and one short-answer question. The version we are using now contains 10 questions in the pre-test, 9 multiple questions and 1 short-answer question, and 11 questions in the post-test, 10 multiple questions and 1 short-answer question.

Most of the questions in pre-test and post-test are identical, which made it easier to compare the changes in student data before and after. For example, "How much do you know about Civil and Environmental Engineering?" "How interested are you in STEM disciplines?" "Will you choose Civil and Environmental Engineering as your major?"

2) Google Form and EXCEL

For data collection, we used a paper version and an online questionnaire created with Google Forms. Based on the number of questionnaires returned, we found that using the paper version would guarantee a high return rate. We used Google forms and EXCEL to compare the changes in students' interest in their majors before and after the project.

C. Procedure

1) The Introductory Lecture

The introductory lecture for freshmen is offered through the UNIV 100 Student Success course. With the help of the course professor, we used four hours of the course to give the students an introductory lecture of the civil and environmental engineering major and take them on a lab tour. Before the lecture and the tour, students were told that this short survey was to learn about their understanding of Civil and Environmental Engineering at JSU and this questionnaire was anonymous. Findings gathered from this survey will be aggregated in a research report. And the results are only for research use.

The introductory lecture provides students with basic information about civil engineering programs, such as skills required, curriculum, degree plan of the program, and career opportunities. Senior students from the CEE department also come to the class to share their experiences with freshmen.

The introductory lecture for high school students is given during the three-week residential summer program. Students will receive the same introductory lecture, but with more understandable examples and language, and the PI will have more time to introduce the CEE program to them during the summer program.

2) The Department Lab Tour

As part of this study, department lab tours are also organized during the I-CUREs session for students to gain a better

understanding of civil engineering in a comprehensive manner. During the lab tour, students were given a realistic view of the profession and were able to develop a sense of professional cognition. Through immersive observation and participation, such as listening to senior or graduate students introducing the function of each lab, what they are doing recently in these labs, including the show of drones flying and controlling, 3-D printing, the concrete canoe building, etc., students will know how the profession fits them and if they intend to learn it in the future.

Likewise, high school students have the same opportunity to visit laboratories, observe and participate in cutting-edge technology demonstrations. In addition, the summer program for high school students originally includes a variety of activities designed to improve their skills in Science, Technology, Engineering, and Mathematics (STEM) and leadership—which could guide high school students to make good future career plans—by arousing their interests in science and technology engineering and enhancing their engineering skills through the form of teamwork.

3) The questionnaire

Those two questionnaires mentioned above were distributed to the students before and after the introductory lecture and the lab tour. For the high school students, there are some adjustments about the expression. The main purpose of the two questionnaires is to compare whether there was a change in students' interest and understanding of the CEE major and whether there was a change in their intention to major before and after the program.

III. RESULTS

Considering that the students participating in the project were in different terms and that the introductory lectures and laboratory tours were not conducted simultaneously but instead in separate sessions, this resulted in inconsistencies between students participating in both the pre-test and the post-test. Therefore, a total of 27 pairs of questionnaires (54) were used to compare. The data analysis was divided into two levels: an overall profile analysis using all data and a pre-post comparison analysis using paired data.

A. Freshmen show little interest in Civil and Environmental Engineering in JSU

Of all 66 freshmen who took the pre-test, 77% (51 students) chose they were not interested in CEE major, of which 45% were not interested in it at all, and 32% chose “not interested in it very much”. Only 4% were very interested in the CEE major(See figure 2).

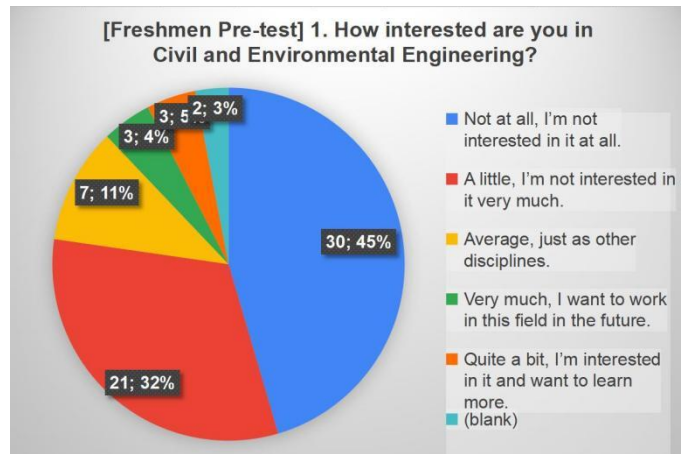


Figure 2. All freshmen pre-test question one and responses.

B. High school students show some interest in Civil and Environmental Engineering in JSU

For high school students, 61% of them have a moderate or higher level of interest in the CEE program, Of which, 26% were very interested in the program and wanted to learn more about it, while 36% were moderately interested in the program. And only 13% are not interested in it at all(See figure 3).

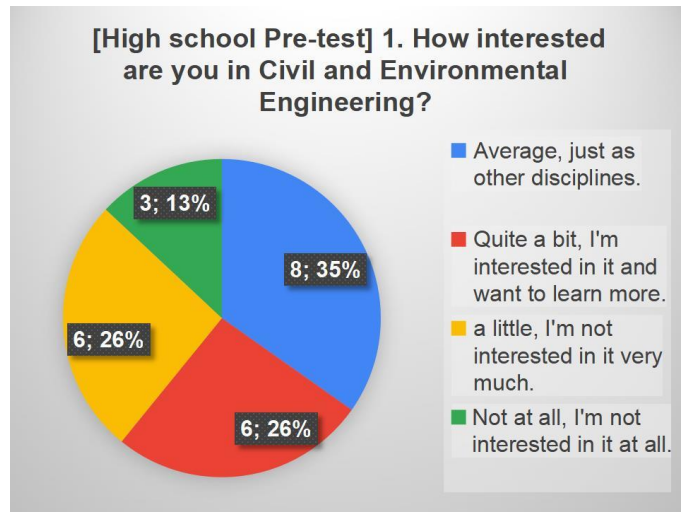


Figure 3. All high school students pre-test question one and responses.

C. STEM disciplines are not particularly appealing to freshmen in JSU.

Of all 66 freshmen who took the pre-test, only 6% students are very interested in STEM disciplines, and 15% students are interested in it quite a bit. 26% students show moderate interest in STEM majors, 26% students have a little bit interest in it, and 24% students are not interested in it at all(See figure 4).

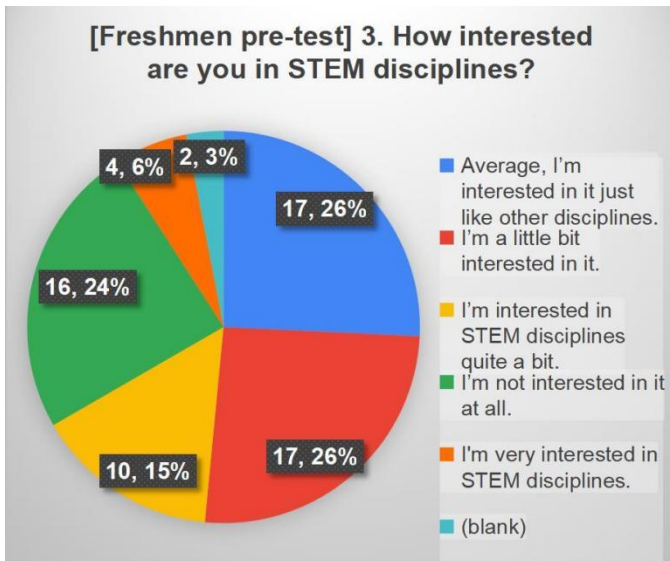


Figure 4. All freshmen pre-test question three and responses.

D. High school students show strong interest in STEM-related occupations

As shown in Figure 5, 39% high school students are interested in STEM related occupations quite a bit; 31% of them show moderate interest in STEM related occupations; 13% of them are very interested in it, and only 17% students show little or no interest in it.

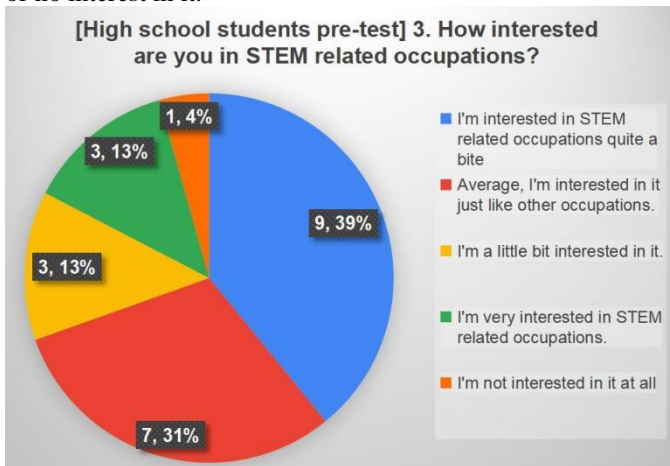


Figure 5. All high school students pre-test question three and responses.

E. Students' interest in the CEE major did not change significantly before and after the test

Although not a lot of students did both tests, we can still see in Figure 6 that the data of both tests did not change much with only one more or less in each response. We might even say that the results were slightly pessimistic, with the tiny change reflected in the shift from somewhat interested to somewhat disinterested.

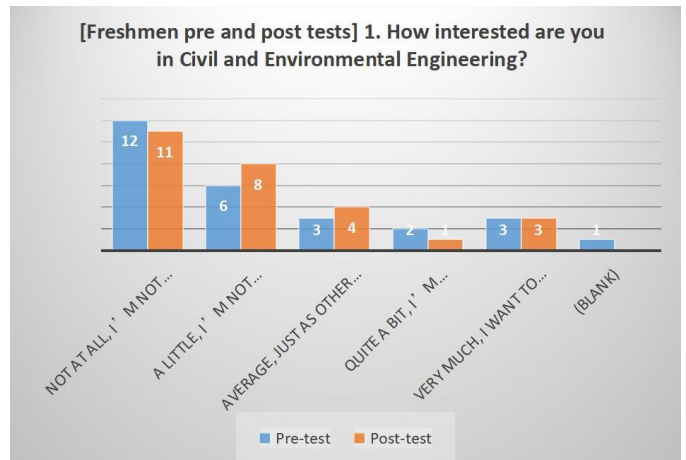


Figure 6. Freshmen pre and post tests question one comparison.

F. A modest increase in students who indicated they might major in CEE in the future.

In Figure 7, we can see that although the changes are relatively small, all the changes point to the possibility that there might be a little bit more students choosing this major in the future.

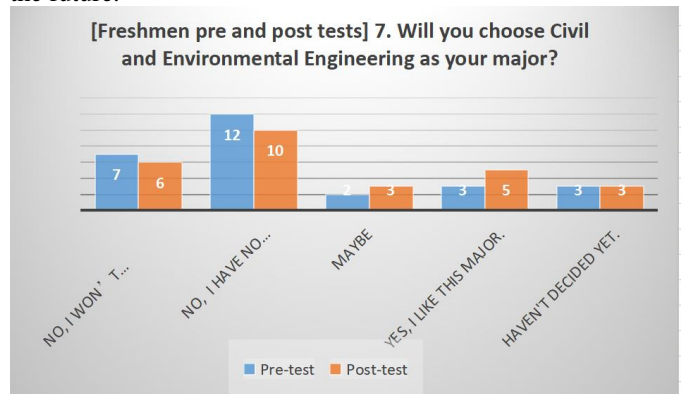


Figure 7. Freshmen pre and post tests question seven comparison.

G. The Introductory lecture and lab tour were helpful for students' choice of major

Although there was no appreciable rise in interest in the CEE major in terms of data, many students expressed that the introductory lecture and lab tour offered by the CEE department taught them something and assisted them in choosing their future majors (See Figure 8). For the open question in post-test "Is there anything else in respect of Civil Engineering you want to learn other than what we provided in the introductory lecture? What is your opinion on the introductory lecture and the lab tour?" Some students wrote that "No, my opinion is that the tour was amazing and the labs are very beautiful." "I was able to learn more about the department, and the lab tour was very helpful." "There are not any other things I'd like to know but I think the tour was very nice and well put together." "Civil engineering is a great major if you've interested based off the information I was given."

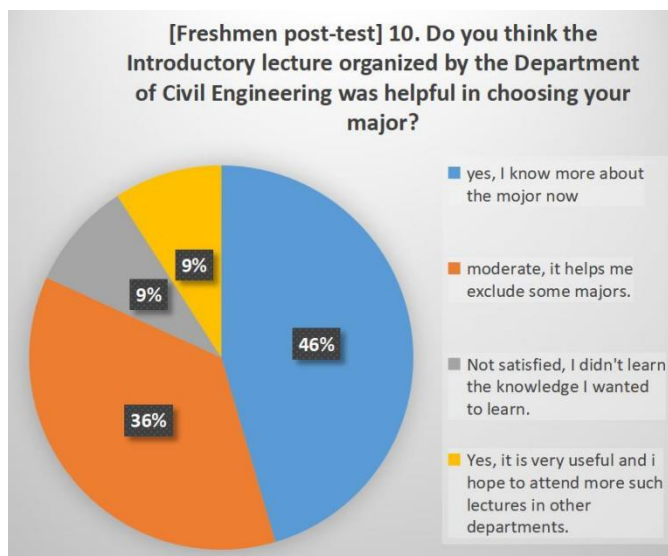


Figure 8. Freshmen 2023 spring post-test question ten and responses.

IV. DISCUSSION

A. Summary of results

The results of the study indicate that freshmen show little interest in STEM disciplines, including the major we piloted this time — the CEE major, while high school students are relatively more interested in STEM related occupations and the CEE major. The I-CUREs experience is helpful in a student's choice of future major but may not lead to their choice of the major in this pilot.

B. Interpretations and implications

A review of all participants' major interests prior to their attending in I-CUREs showed that most of freshmen were not originally interested in STEM and CEE at all, which make it very hard to change their mind.

However, with the help of this special experience, freshmen were given the chance to get access to the professional knowledge and lab tours. For those who are not interested, this experience not only help them avoid the risk of blindly choosing a major, but also saves students time and money; for those who are interested, this experience will strengthen their confidence. Therefore, the I-CUREs experience is helpful for students' choice of major.

High school students may be a breakthrough in increasing enrollment in STEM-related majors. It is clear from the data we collected that high school students are slightly more interested in STEM majors and CEE majors, so by working with more high schools to introduce students to STEM-related majors and by taking advantage of the ample summer program schedule, students can be exposed more in the cutting-edge technology research and even get involved in it.

C. Limitations

The samples of the paired questionnaires are not enough. The research results may not be applicable to all HBCUs. Due to the lack of experience at the beginning of the study and the poor control of the lab tour timing, some students were in a hurry to leave for their next class and failed to fill out the post-test questionnaire, while there was no effective supervision method for students to complete the online questionnaire, resulting in the post-test not being collected effectively.

D. Recommendations

Due to conditions, some of our initial ideas did not come to fruition. For future research, if conditions permit, we propose to offer a general elective course in STEM professional experience. It is desirable to combine the various STEM majors in the university and to allocate a certain number of hours to each major. In addition to an introduction to the field of STEM majors and laboratory tours, there will be readings on cutting-edge materials, experiences in cutting-edge technologies, assignments and group discussions as we planned in the beginning. This allows students to see what knowledge and skills they need to learn as a student in a particular major. With the course as a foundation, it will be easier to collect the questionnaires. Also, with multiple majors to choose from, students will have a clearer idea of their future major direction.

In addition, cooperating with more high schools might be a great way to increase the STEM student population.

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