Course-based Undergraduate Research Experiences at HBCUs

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Abstract

Course-based undergraduate research experiences (CURES) is an academic mitigation strategy that has the potential to prepare HBCU undergraduate students for graduate programs in STEM and the workforce by engaging students in real-world research experiences. Given the financial obstacles faced by many HBCUs, the CURES approach is a cost-effective training method for engaging large numbers of students in relevant research projects in STEM. CURES allow students an opportunity to investigate a novel biological problem, develop a testable hypothesis, utilize specialized equipment, and obtain crucial training to generate results that positively benefit the larger scientific community.

CURES in STEM offer opportunities for meaningful undergraduate mentoring experiences for HBCU students. Moreover, implementing this research-training strategy affects diversity and inclusion because every student enrolled in the department can engage in the research endeavor. CURES implementation consists of three components: 1) faculty/staff CURES curriculum training, 2) CURES-based intervention for STEM undergraduates, and 3) evaluation procedures to determine effectiveness. Future science education studies must ascertain how CURES impact HBCU student learning and interest in graduate school and the STEM workforce.

Keywords: research, HBCU, mentoring, inclusion, CURES

Introduction

Over the last decade, there have been calls from major national reports to reform undergraduate Biology education (Bio2010). Specifically, organizations recommend integrating research experiences in the Biology course curriculum for all majors regardless of classification. The rationale for this proposition stems from evidence that shows how early and consistent undergraduate research experiences improve student satisfaction, academic success, and other important factors that facilitate the transition to graduate school or research career (Bowman & Holmes, 2018; Flowers, 2019a; Flowers, 2017; Flowers, Moore, & Flowers, 2016; Lopatto, 2007; Moore, Flowers, & Flowers, 2014). Unfortunately, due to various factors that exist on most college and university campuses, it is estimated that less than 3% of the student body population will have an opportunity to engage in faculty-mentored research during their undergraduate career. In terms of undergraduate research opportunities at HBCUs, the reality is dismal. Specifically, HBCUs are plagued with insufficient research infrastructures, time, and economic resources to engage a large number of underserved students in hypothesis-driven research experiences consistent with labor force competency requirements. This is unfortunate given the evidence that suggests that minority student exposure to undergraduate research experiences correlates well with increased retention, engagement, self-efficacy, career interest, and the probability of pursuing a STEM career after graduation (Bangera& Brownell, 2014; Shuster et al., 2019).

Structured faculty mentoring experiences inherent in discovery-based research endeavors have also shown great promise to alleviate academic and professional ills that continue to produce morose diversity statistics in STEM education and the STEM workforce. A recent study demonstrated that college students perceived that mentoring and professional development (e.g., publishing) were beneficial aspects of CURES (Dillon, 2020). Over three-quarters of the research participants responded favorably when probed about pursuing graduate education opportunities. Moreover, a study published last year compared CURES and non-CURES biology teaching labs and found that CURES students reported a higher level of student-faculty interaction than non-CURES students. It was also shown that higher interaction leads to higher scores on student motivation and collaboration scales (Esparza, Wagler, &Olimpo, 2020). Not surprising, the literature base that addresses HBCU student perceptions, faculty perceptions, and educational outcomes concerning CURES is virtually nonexistent. Ensuring student preparation for the workforce is a significant objective of STEM educators in the 21st century. It encompasses existing standards established by governing bodies tasked with improving outcomes at colleges and universities in the United States (Association of American Colleges and Universities, 2007).

Preparing qualified students for STEM employment must involve using evidence-based pedagogical strategies that enhance retention of discipline-specific content and utilization of science process skills and communication skills required by today's employers.

Course-based Undergraduate Research Experiences Conceptual Framework

CURES are a high-impact student-centered faculty-mentored active training and learning strategy. Students participate in a hypothesis-guided research study designed to elucidate novel findings in a classroom or laboratory setting. CURES creates opportunities for many students enrolled in a STEM course to engage in discovery-based research projects and serve to improve faculty research productivity. CURES contain five design components (Figure 1).During a CURES project, undergraduate students participate in: research activities, discovery-based explorations, scientific work relevant to the scientific community or society, collaborative processes, and iterative experimental investigations (Auchincloss et al., 2014; Rowland et al., 2018). CURES are distinct from other instructional strategies that do not possess all of the components mentioned above. Recently, Brownell and Kloser (2015) created a framework to incorporate CURES instructional and evaluation practices in the curriculum.CURES are far superior to traditional "cookbook" laboratories where the final experimental results are known, and experiments typically work the first time. Instead, CURES mimic actual academic and industrial labs by engaging students in an experience that places the evidentiary burden on students to work iteratively to accomplish research goals. CURES challenge students to think and work like a scientist.

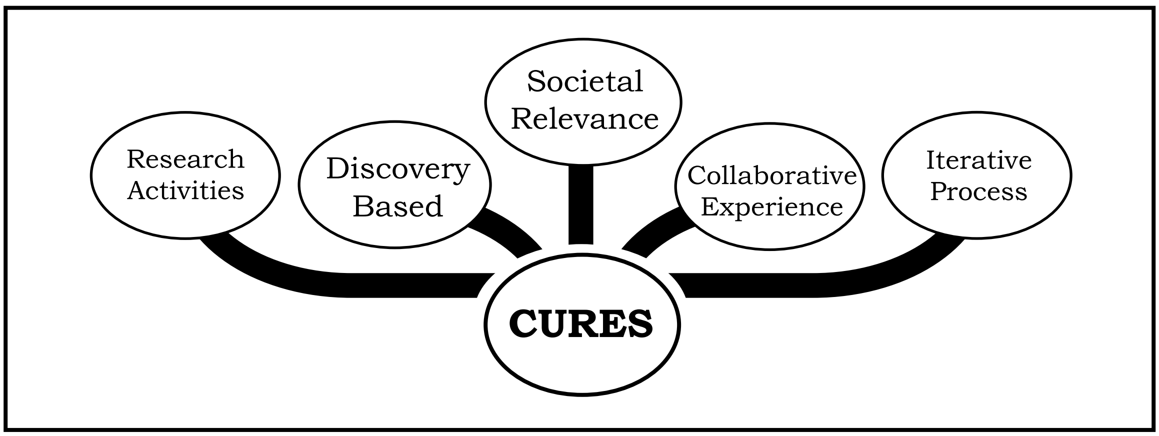

Figure 1. Five CURES design components incorporated in instructional and training activities.

There are many factors at many academic institutions that result in the lack of student engagement in authentic research experiences. Data indicates that underrepresented minorities are historically excluded from joining campus laboratory groups. CURES offer a mechanism for colleges and universities to create equitable opportunities for large numbers of students, especially minority students, to engage in the research process. An inability to actively participate in research experiences accounts for higher academic failure rates and lower retention and graduation rates for underserved communities (Flowers, 2020).

Review of CURES in STEM

In recent years, an increasing number of CURES have been developed and studied for many scientific disciplines (Kinner& Lord, 2018; Marsiglia et al., 2020; Reeves et al., 2018; Stoeckman, Cai, & Chapman, 2019). Increasing empirical evidence indicates that CURES positively impact many educational and professional dimensions that are important to undergraduate education stakeholders (Auchincloss et al., 2014). Data also supports the notion that CURES, directly and indirectly, affect student perseverance in STEM (Corwin et al., 2018). Using the Undergraduate Research Student Self Assessment (URSSA), Sandquist, Cervato, and Ogilvie (2019) demonstrated that implementing a CURES produced increased affective and behavioral gains in first-year students. A modified URSSA was used to assess student learning gains perceptions in which students either participated in a geoscience-focused CURES or a traditional faculty-mentored research experience. Results produced from the study revealed that CURES students exhibited more significant improvements on the "Thinking and Working Like a Scientist" scale compared to students who participated in apprenticeship-style research experiences (Kinner& Lord, 2018).

Results from a cell and molecular biology-focused CURES suggests that students who participated in the CURES demonstrated higher content knowledge and motivation (Olimpo, Fisher, &DeChenne-Peters, 2016). CURES participants also showed a higher degree of self-determination and problem-solving skills using quantitative techniques. This study also applied a qualitative approach to ascertain a link between select CURES elements and outcomes. Using this method, students benefited from the autonomy and collaboration fostered using the authentic research experience. Pagano, Jaworski, Lopatto, and Waterman (2018) employed the CURE Survey to measure an inorganic chemistry laboratory course's effectiveness. Following an independently course-based research project designed to elucidate new chemical enzyme regulators for ammonia borane dehydrogenation reactions, students showed an improved understanding concerning the nature of science and developed an appreciation for conducting research.

Additionally, the CURE Survey assessed the efficacy of a medicinal chemistry-focused CURES. Undergraduates who completed the project to synthesize and characterize anti-inflammatory and antimalarial compounds showed higher gains than non-CURES students (Hall et al., 2018). A CURES treatment group in a physiology psychology lab course showed more favorable dispositions toward science and reported that CURES activities contributed to their plans to consider graduate school or a career after graduation (Lloyd, Shanks, &Lopatto, 2019). An astronomy-focused CURES was shown to increase college students' confidence in participating in scientific endeavors and led to a greater understanding of how to analyze astronomical data and the significance of communicating research findings to the scientific community (Wooten et al., 2018).Using a design-based approach, biology educators developed a CURES in the Biology curriculum that employed a pretest, posttest, and focus group evaluation strategy. Data analysis revealed an overall gain in confidence in scientific inquiry skills. Results also indicated that students developed more expert-like perceptions of biology while participating in the CURES (Mordacq et al., 2017). Interestingly, the knowledge and perception gains are more pronounced and have a larger effect size in the second year of implementation. This suggests that increased exposure to CURES activities improve knowledge and psychological factors over time. Chase et al. (2017) reported statistically significant differences in students' critical thinking scores following a chemistry-based CURES. Students also reported higher interest in chemistry, which was mediated by the laboratory tasks' authentic nature.

CURES have also been shown to improve graduation rates in STEM. CURES students were more likely to earn their college degree versus non-CURES students (Rodenbusch et al., 2016). Moreover, CURES students have reported similar perceived gains compared to students who participated in off-campus internships (Drew & Triplett, 2008). CURES assessment studies have primarily explored the effects of the entire experience on student outcomes and perceptions. However, a few studies have investigated the link between CURES implementation elements on short-term, immediate, and long-term outcomes. Hanauer and Dolan (2014) designed the Project Ownership Survey to examine project ownership's role in student outcomes. A year later, Corwin, Runyon, Robinson, and Dolan (2015) designed the Laboratory Course Assessment Survey to measure student perceptions of CURES design elements.Future studies should investigate the impact of individual CURES components on HBCU students' educational and professional outcomes. CURES component-outcome analysis studies will positively contribute to the CURES knowledge base and further validate this instructional strategy. Following a review of the literature, it is clear that the majority of the current studies on the effects of CURES outcomes focus on non-HBCUs. However, a study conducted at North Carolina Central University indicated that students who participated in course-integrated chemistry analytical authentic research projects displayed higher excitement about pursuing a chemistry career (Kerr & Yan, 2016). Existing evidence on HBCUs and CURES reinforces the need for additional work in this area.

Biology CURES Implementation

HBCUs face prodigious financial challenges each semester and year after year display sagacious utilization of dwindling endowments. Further, HBCUs face more significant accreditation obstacles than other higher education institutions (Burnett, 2020). Many HBCU students express a desire to engage in undergraduate research; however, infrastructural limitations preclude many students from working in campus research laboratories. HBCU STEM faculty are encouraged to design and implement and assess a strategy that would infuse undergraduate research into the curriculum to allow every STEM major an opportunity to participate in hypothesis-driven research. CURES represent a fiscally responsible and sustainable pedagogical approach to involve many STEM undergraduate students in authentic research. The research questions, goals, tasks, and topics in a carefully designed CURES are consistent with academic and industrial labs and enhance student preparation for graduate school and the workforce. CURES impact on academic and job-related outcomes is illuminated in recent science education research articles (Kerr & Yan, 2016; Kinner& Lord, 2018; Williams & Reddish, 2018).

CURES promote the integration of workforce-ready research training into the undergraduate STEM curriculum. Early exposure to CURES is beneficial in enhancing academic persistence and has been shown to improve the STEMployability of minority students (Flowers, 2017; Indorf et al., 2019). CURES curriculum plans in STEM could involve multiple courses and allow each student in a specific department to engage in a novel research project. Pedagogical methods should include flipped methods, online modules, and virtual reality to enhance comprehension of core scientific concepts (Flowers, 2018; Flowers, 2019b). CURES course activities should involve question and hypothesis identification, bibliographic exploration, experimentation, data collection, data analysis, data presentation, and scientific communication tasks at the end of each semester.

Conclusion

HBCUs are filled with a proud history of providing quality education and professional training experiences to minority students. Unfortunately, however, African American students are often the victim of discrimination, even at some HBCUs, when it comes to being selected for inclusion in research labs. The lack of robust hypothesis-driven research experiences has been reported as factors that inhibit minority undergraduate transit through the STEM pathway (Flowers, Moore, & Flowers, 2016). The United States' economic prosperity ultimately depends on the nation's ability to educate and hire a high-quality, culturally diverse STEM workforce. I contend that a better prepared HBCU populace will lead to a more diverse STEM labor force, a national imperative. The production of qualified historically underrepresented STEM graduates will require the development, utilization, and statistical evaluation of novel pedagogical approaches aligned with current employer expectations (Jang, 2016).

The restructuring of existing traditional teaching labs to include the exploration of research questions that are paramount to society and that focus on scientific communication create capacity for every HBCU student enrolled in a particular STEM course to participate in the research process. While CURES can be completed in one class, the best experiences consist of completing various project stages in multiple courses. The multi-course approach is more complicated and requires departmental cooperation and expertise; however, the multi-course system is helpful because it reflects the graduate school and workforce research environment. Little is known about the effects of CURES on HBCU student knowledge gains and critical psychosocial constructs. Future experiments containing a treatment group (e.g., CURES) and a control group coupled with industry-standard statistical analysis will help determine the efficacy of CURES as it relates to HBCU students. Studies involving qualitative student and faculty components will also be a beneficial mechanism to fully understand how CURES impact HBCU faculty and student educational outcomes. HBCU STEM faculty interviews will lead to the generation of best practices in CURES consistent with HBCU budgets and culture. Information synthesized from these research projects will promote the development and sustainability of novel teaching and training strategies.

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