Research Paper

# Exploring OER as a Mediator for Equity Gaps in Student Course Success Rates for Introductory Biology Courses in the NCCCS

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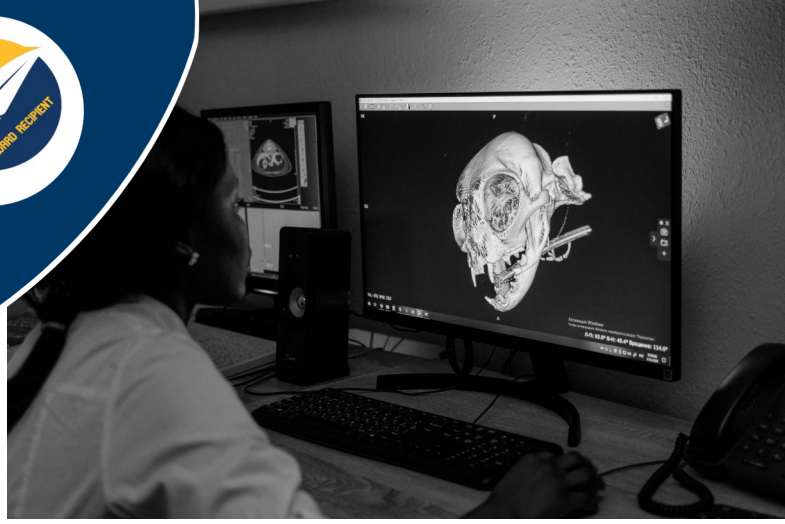


**Abstract**

From reducing costs (Dimeo, 2017; Saldutti, 2017) to enhancing instructor autonomy (Bongiovanni & Buljung, 2020) and improving student success (Colvard & Watson, 2018; Winitzky-Stephens & Pickavance, 2017), Open Educational Resources (OER) have been impactful to the higher education sphere. The potential of implementing such resources has led organizations, like NC LIVE, to incentivize adoption through the application and distribution of faculty grants. The Open Education North Carolina (OENC) grant has been shown to improve success rates in introductory biology courses in North Carolina community colleges (Marsh & Chesnutt, 2021) but the question remained, which students benefited most? This study viewed the OENC grant as a proxy for adoption of OER and examined the impacts of the grant program on equity gaps in colleges employing faculty receiving an OENC award. After application of a propensity score matching algorithm, the authors of this study identified that success gaps between students identifying as White and students identifying as Black/African American or Hispanic/Latinx were significantly decreased during the implementation year of an OENC award to a faculty member at that institution. This study further reinforces the body of academic literature supporting the application of open resources in STEM and adoption as a means for decreasing equity gaps in North Carolina community colleges. *Keywords:* open educational resources (OER); equity; success gaps; science, technology, engineering, mathematics (STEM)

## Exploring Open Educational Resources as a Mediator for Equity Gaps in Student Course Success Rates for Introductory Biology Courses in the North Carolina Community College System

Access to resources that can support teaching and learning in the current age of information is of interest to educators and educational researchers at all levels and content areas. Such resources that come at no cost to the user, often referred to as Open Educational Resources (OER), can be accessed by a broad audience and have the potential to shift teaching and learning in a variety of contexts. OER in science, technology, engineering, and mathematics (STEM) content areas have been under investigation for myriad reasons, including the cost of attending many STEM based courses (Dimeo, 2017; Saldutti, 2017), the customizability and access to course resources (Bongiovanni & Buljung, 2020), and student success rates (Colvard & Watson, 2018; Marsh & Chesnutt, 2021; Winitzky-Stephens & Pickavance, 2017). Proponents of open resources argue that the cost passed to students in STEM based programs can range from hundreds to thousands of dollars a year for books and materials (Bongiovanni & Buljung, 2020); however, others note that the quality and accessibility of such resources can annul any potential benefits of such an adoption (Melnikova et al., 2017). Differences in opinion of the costs and benefits of open resources notwithstanding, scholars report that students in courses utilizing OER believe that these resources comparably align with, or are slightly better than, texts used in other courses (Hendricks et al., 2017), and that belief translates

into higher grades and an increased number of students successfully completing courses (Winitzky-Stephens & Pickavance, 2017). Although many studies have focused on general student success (students successfully completing coursework with a grade of C or higher), this study explores OER as a potential mechanism for addressing inequities in student success in STEM courses. The disparity in STEM course success rates between minority (i.e., Black/African American, Hispanic/Latinx) students and White students (Arnim, 2019) warrants further investigation of potential resources that might support all students. Variables such as access (Schneider et al., 2006) and costs (Krogstad, 2016; Schneider et al., 2006) have been shown to play an important role in enhancing educational opportunities for historically underrepresented students. Since OER has been shown to reduce the costs of educational resources for students (Bongiovanni & Buljung, 2020), there is a need to examine the impact of OER in STEM based courses for students across racial/ethnic groups.

### *The OENC Grant Program*

Open Education North Carolina (OENC) is an initiative hosted by NC LIVE that supports the adoption of open educational resources in North Carolina's community colleges and universities. This initiative, in part, funded $1000 adoption grants to individual faculty applicants to support their training and implementation of these resources. Upon application, faculty members must provide evidence of their eligibility as a faculty member employed by an NC LIVE member institution, indicate that there would be significant cost savings to students, and be prepared to adopt an open educational resource as the primary textbook for their course ("OENC Grant Application," n.d.). Although grant awardees came from a variety of subjects and institutions between 2018 and 2020, 103 grants were awarded to faculty employed by NC community colleges and 36 were focused on implementation in STEM coursework ("OENC: Awarded Grants," n.d.). Incentivizing faculty to utilize OER is an area of research that has potential for increasing OER opportunities for students.

Providing financial incentives for faculty members to adopt OER has been shown to increase adoption of OER (Bongiovanni & Buljung, 2020; Todorinova & Wilkinson, 2020). Incorporating new resources into an existing curriculum can be challenging. Aligning content from a syllabus or course outline to a new text, particularly when the burden of alignment is carried primarily by an instructor without the aid of a publisher, is time consuming and commendable. Furthermore, merely finding available resources is a barrier; however, financial incentives can assist faculty members assuming this task and can even promote faculty members in their own authorship of their course texts when other texts are unavailable (Todorinova & Wilkinson, 2020). By providing appropriate incentives for faculty adoption, universities and colleges are more likely to see more OER implementation by their faculty members (Annand & Jensen, 2021). The body of academic work around this area of focus highlights barriers to faculty adoption of OER but has concurrently shown open resources to provide new opportunities to increase student success and address success rates for historically underrepresented students in STEM courses.

## Literature Review

Though not without its challenges, adopting open resources has the potential to benefit students financially and academically (Dimeo, 2017). Given this, many researchers have supported the adoption of open resources in courses that have exhibited higher non-tuition costs and those that maintain lower course success rates (Marsh & Chesnutt, 2021; Winitzky-Stephens & Pickavance, 2017). While concurrently impacting all students, historically underserved populations have been disproportionately impacted by the financial burden of coursework or coursework that is not suited to their individual needs, which can lead to lower success rates (Jenkins et al., 2020; Shaw et al., 2019). This is especially true when dealing with courses in STEM which already garner lower success rates for students of historically underrepresented populations such as African Americans, Latinxs, and Native Americans (Hurtado et al., 2010). OER presents a unique opportunity to address some of these inequities by decreasing cost related barriers to educational resources.

### *OER in STEM*

The implementation of OER in STEM based courses has been shown to reduce student costs on course related materials and provide students with similar

or better resources when compared to their non-OER courses (Bongiovanni & Buljung, 2020; Hendricks et al., 2021). Additionally, many OER based courses provide a customizable approach to instruction, which has been reported to be particularly helpful in STEM courses (Bongiovanni & Buljung, 2020). In an investigation of open educational resources in an entry level physics course, 57% of students did not purchase a textbook due to its cost and 40% dropped a specific course due to the cost of a given textbook (Henricks et al., 2021). Researchers also determined a significant difference in the number of students who completed an introductory biology course when OER were available versus when they were unavailable to students (Fisher et al., 2015). While OER presents many opportunities to reduce costs and enhance course materials, OER is still not the normal means of delivering content to students in STEM courses (Dimeo, 2017).

In a survey of 400 college professors, over 200 instructors had no experience in using OER (Dimeo, 2017). While some institutions are providing financial incentives to adopt OER, there remain individuals teaching in STEM fields who are either unaware of the availability of OER for their content area or unaware of the programs that incentivize such adoption (Bharti & Leonard, 2021). According to a study of students attending the Colorado School of Mines, students were expected to spend over $1,500 on books and supplies each year (Bongiovanni & Buljung, 200). While these costs may not be detrimental to all students, this can have detrimental implications for students from lower socioeconomic levels. Currently, over a third of Black/African American and Hispanic/Latinx students leave STEM majors compared to White students (Arnim, 2019). One of the reasons researchers speculate for this disparity is that many minority students come from low income families and do not have access to high cost educational resources (Arnim, 2019). While OER is important specifically for disparities of representation in STEM fields, OER also addresses issues within the greater spectrum of educational equity.

## Equity in OER

The rising costs of textbooks present a barrier for students as a non-tuition expense for those pursuing higher education. These barriers disproportionately impact underserved populations and serve as a redistributive justice issue for many students (Jenkins et al., 2020). Beyond costs, other researchers have lauded open resources as being customizable because they provide instructors with the opportunity to differentiate instruction to the diverse needs of their students (Jenkins et al., 2020; Shaw et al., 2019). With customizability in mind, instruction must be driven through an equity oriented process to provide equal access for all learners (Kalir, 2018).

The benefits of OER have been well documented with respect to costs, differentiating instruction for diverse populations, and benefiting student performance in underserved populations. For example, Colvard & Watson (2018) investigated the impact of open resources on a variety of student metrics that included students from lower socioeconomic backgrounds and those from historically underserved populations. In their study of nearly 20,000 students, they found that not only did non-White students benefit from open resources when reporting their academic performance, but their improvement exceeded the improvement of White students in the study. Their findings added to a body of literature that supports the use of open resources as a mechanism for social justice.

Open resources may benefit Hispanic/Latinx students more than any other group. Hispanic/Latinx students are far more likely to enroll in two-year colleges citing the reduced cost of attendance (Krogstad, 2016; Schneider et al., 2006) and location relative to their home (Schneider et al., 2006). As costs play a significant part in the decision to enroll in higher education, providing low or no cost options for textbooks may play a significant role in accessibility of these resources (Jenkins et al., 2020). In addition to costs, the modifiable nature of open resources (Saldutti, 2017) provides instructors an opportunity to meet the needs of students who are more likely to be nonnative English speakers and who are more likely to be first generation, or the children of first generation, immigrants (Schneider et al., 2006).

### *Potential Disadvantages of OER Adoption*

Although there is a wealth of research espousing the benefits of OER adoption, many authors would caution potential adopters. Melnikova et al. (2017) conducted a comparative analysis of faculty members from a wide array of disciplines. In this analysis, many of the aforementioned benefits were echoed

by their respondents; however, respondents were also careful to chronicle some concerns. Of these disadvantages, respondents noted that quality was a major concern as peer review and author experience are not requirements for many resources. Second, with many open resources having electronic only access, the burden of access is placed on the student to obtain devices and internet service capable of retrieving the information. Third, although there is a mechanism to obtain copyright protections through Creative Commons, many find the copyright process cumbersome. Finally, academia is in part funded through royalties to authors and revenue generated through the campus bookstore. Large scale OER adoption may impact these revenue streams (Melnikova et al., 2017).

## Gaps in the Literature

While previous research has examined the impacts of OER for underserved students in STEM coursework, less is known about the impacts of OER from an institutional lens with the added incentive of stipends to the faculty for such adoption. The OENC grant program applied in introductory biology courses provided an opportunity to address that gap.

## Research Questions

This research was guided by two specific questions with three research subquestions that will be addressed through data collection and analysis.

1. Was there a statistically significant decrease in the equity achievement gap, measured by the percentage of successful student completers, in introductory biology courses for colleges that employed an OENC grant recipient in the impact year of the OENC grant?
    a. Was the decrease evident in a comparison of White students and Black/African American students?
    b. Was the decrease evident in a comparison of White students and Hispanic/Latinx students?
    c. Was the decrease evident in a comparison of Black/African American and Hispanic/Latinx students?
2. If such a decrease was evident, what was the estimated effect size of the decrease?
    a. What was the estimated effect size of the decrease in a comparison of White students and Black/African American students?
    b. What was the estimated effect size of the decrease in a comparison of White students and Hispanic/Latinx students?
    c. What was the estimated effect size of the decrease in a comparison of Black/African American students and Hispanic/Latinx students?

## Methods

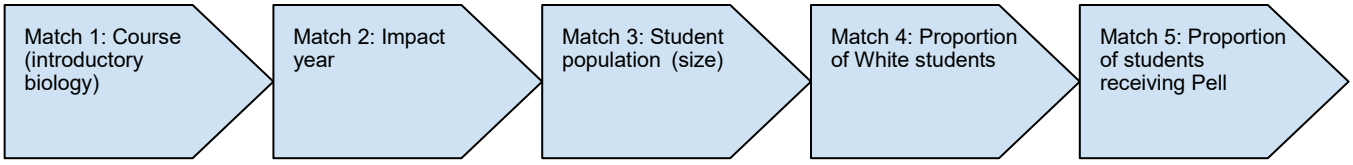
This study's treatment group was set based on the availability of the OENC grant to North Carolina community colleges. Although there were multiple STEM instructors of different disciplines, introductory biology courses were selected for specific scrutiny to align with the work of Marsh and Chesnutt (2021). Any college that employed a faculty member who received an OENC award for introductory biology coursework was observed according to the variables listed in later parts of this section. In order to observe potential impacts of the OENC grant on student success, a comparison sample was developed using a propensity matching algorithm.

## Obtaining a Matched Sample

Following the recommendations of Caliendo and Kopeinig (2018) a propensity matching algorithm was developed to identify colleges that were most similar to those in the treatment group. The algorithm used for this study is visualized in Figure 1

**Figure 1**

*Propensity Matching Algorithm*



The result of the propensity matching algorithm produced a sample of comparison colleges (n=9) that all offered coursework in the same course numbers as those in the comparison group. Additionally, the comparison colleges maintained observable data from the year prior to and after faculty at treatment colleges were awarded the OENC grant. As for matches 3, 4, and 5, two-sample *t*-tests were implemented to determine the degree to which comparison colleges differed from those in the treatment group. Table 1 displays the results of those tests.

**Table 1**

*Student* t-*Test Results for Matches 3–5*

| Match Number | Group | Mean | *t*-Score | *p*-Value |
|---|---|---|---|---|
| Match 3 | Control | 4833 | 0.032 | 0.975 |
| | Treatment | 4799 | | |
| Match 4 | Control | 0.6033 | -.772 | .451 |
| | Treatment | 0.6300 | | |
| Match 5 | Control | 0.336 | 1.106 | .285 |
| | Treatment | 0.317 | | |

Analysis of the table above would indicate that the comparison group created through the propensity matching algorithm was not statistically different from the treatment group as evidenced by *t*-scores not significantly deviating from zero. In the case of Match 3 (student population size), the comparison group created through the matching algorithm maintained an average student population size only slightly larger than the treatment group, but that difference was negligible when tested for statistical significance ($t$=0.032, $p$=.975). As for Match 4 (proportion of White students), the treatment group on average contained a slightly larger proportion of White students than the comparison group, but that difference was negligible when tested for statistical significance ($t$=-.772, $p$=.451). Finally, Match 5 indicated that the average proportion of Pell grant recipients in the control group was slightly larger than the treatment group, but that difference again was negligible when tested for statistical significance ($t$=1.106, $p$=.285). These findings indicate that the matches developed through the propensity matching algorithm were sufficient to meet the guidelines recommended by Caliendo and Kopeinig (2018) for comparison.

### *Defining Student Success*

Student success is a metric that is often operationally defined by authors. For the purposes of this study, student success has been defined simply as successful completion of the course with a grade of C or higher. As many of the courses under review by this work are considered college transfer courses, students must obtain a grade of C or higher at the conclusion of the course to be considered for transfer under the Comprehensive Articulation Agreement (CAA) between the North Carolina Community College System and the University of North Carolina System (Board of Governors, 2014). Although certain courses may not meet the conditions of the CAA, student success for those

courses was assessed using the same metrics.

**Data Collection Procedures**

Once a reasonable match had been established, each institution in both the control and treatment groups were observed. Data were made publicly available by the North Carolina Community College System ("Curriculum Course Outcomes by Student Demographics," n.d.) documenting student success in introductory biology courses. These data were available in both aggregated and disaggregated formats related to student demographics (sex, race, etc.). The availability of the data was somewhat restricted in that the NCCCS suppressed data from any group that registered fewer than 20 members. This fact limited this study in disaggregating the data for certain ethnic groups. As such, those comparisons were removed for observation. Table 2 lists each variable collected for the purposes of analysis.

**Table 2**

*Description of Variables*

| Variable Name | Variable Type | Description |
|---|---|---|
| Course Name | String | The name and course number aligned with the NCCCS Common Course Catalog indicating the type of introductory biolo- |
| Year Awarded | Continuous | The year that the institution was awarded an OENC grant or the year that a matched institution was observed that corre- |
| Group | Binary | A code indicating whether the school was awarded an OENC grant (TREATMENT) or was a matched institution |
| Percent White Success (Pre-OENC Award) | Continuous | The percentage of students that identified as White and successfully completed the selected introductory biology course in |
| Percent White Success (OENC Implementation Year) | Continuous | The percentage of students that identified as White and successfully completed the selected introductory biology course in the year awarded. |
| Percent Black/ African American Success (Pre-OENC Award) | Continuous | The percentage of students that identified as Black/African American and successfully completed the selected introductory biology course in the year prior to the year awarded. |
| Percent Black/ African American Success (OENC Implementation | Continuous | The percentage of students that identified as Black/African American and successfully completed the selected introductory biology course in the year awarded. |
| Percent Hispanic/ Latinx Success (Pre-OENC Award) | Continuous | The percentage of students that identified as Hispanic/Latinx and successfully completed the selected introductory biology course in the year prior to the year awarded. |
| Percent Hispanic/ Latinx Success (OENC Implementation Year) | Continuous | The percentage of students that identified as Hispanic/Latinx and successfully completed the selected introductory biology course in the year awarded. |

## Research Design & Data Analysis

The research questions proposed in this document were best addressed by the comparison of student performance in the courses scrutinized in this study. Data were prepared according to Table 2, and equity gaps (the difference in the percentage of successful students in each identified ethnic group) were calculated in each pre-OENC award and OENC implementation year. These calculated changes in success outcomes constituted either an increase or decrease in each equity gap as a function of the OENC implementation year. Comparisons were constructed to align with the research questions:

- Change in White and Black/African American equity gap (White—Black/African American)
- Change in White and Hispanic/Latinx equity gap (White—Hispanic/Latinx)
- Change in Black/African American and Hispanic/Latinx equity gap (Black/African American—Hispanic/Latinx)

Since each institutional gap was calculated by subtracting the percent success of group two from the percent success of group one, any positive value would indicate that group one maintained a larger percentage of successful students than group two. Once each change had been calculated, two-sample *t*-tests were used to determine if the change in equity gap from the pre-OENC award year to the OENC implementation year were statistically significant. Finally, the effect size for any significant differences were calculated using Cohen's *d*.

## Delimitations

Although precautions were taken to limit the influence of potential bias, this design was delimited by several factors. First, any institution may adopt open resources at the behest of their faculty, students, or administrators without being awarded an OENC grant. As such, it was not possible to determine if any matched institution had already implemented such resources during either of the two observed years. Pursuant to this limitation, this research may not be generalizable to the larger body of work regarding open resources but was carefully applied to OENC recipient colleges. Second, data suppression by the NCCCS made comparisons for certain groups unavailable to the described research design. As such, potential pairs for unavailable comparisons were omitted. Third, the application of a quasi-experimental design was applied in lieu of a randomly controlled trial. Propensity matching is generally accepted as a reasonable approach given the lack of control over the trial (Caliendo & Kopeinig, 2018). Fourth, award participants are incentivized to adopt resources. Although the award funding was not contingent on documenting success, faculty could have been primed to adjust their grading policies to reflect impact, although it is doubtful that such an adjustment would have occurred intentionally. Finally, and perhaps most noteworthy, the span of time for OENC implementation was interrupted by the COVID-19 pandemic. Although the applied propensity matching technique should help filter some of the impacts of the pandemic on student performance as all schools, treatment or otherwise, were affected by the crises, every student, school, and system assimilated those impacts differently. No attempt was made to accommodate for the COVID-19 pandemic beyond observing all schools equally over the same time span.

## Results

The results of this study were partitioned into three sections to organize findings according to the research questions. Descriptive statistics for the variables, significance tests, and effect sizes are given for each comparison of success gaps between White and Black/African American students, White and Hispanic/Latinx students, and Black/African American and Hispanic/Latinx students. All tables can be found in the text.

### Success Gaps Between White and Black/African American Students

Table 3 displays the descriptive statistics for the success gaps between White and Black/African American students for control and treatment institutions for the pre-OENC year and the OENC implementation year.

**Table 3**

*Descriptive Statistics for White and Black/African American Students' Success*

| Statistic | Pre-OENC Year | | OENC Implementation Year | |
|---|---|---|---|---|
| | White—Black/ African American Control (*n*=8) | White—Black/ African American Treatment (*n*=8) | White—Black/ African American Control (*n*=8) | White—Black/ African American Treatment (*n*=8) |
| Mean Gap | 16.94 | 19.88 | 20.00 | 13.88 |
| Standard Deviation Gap | 6.59 | 7.21 | 7.19 | 7.97 |

Pure comparison of the mean gaps for the control group from the pre-OENC year to the OENC implementation year would indicate that the average equity gap for those institutions had increased ($xbar_{Pre\text{-}OENC}$ - $xbar_{implementation}$ = -3.06) whereas the same comparison for the treatment group declined ($xbar_{Pre\text{-}OENC}$ - $xbar_{implementation}$ = 6.00). When the change in gaps was analyzed using a two-sample *t*-test, the difference between the gaps was statistically significant ($t$ =-2.264, $p$ =.04) and the effect of the OENC award was large (Cohen's $d$ =-1.132).

**Success Gaps Between White and Hispanic/ Latinx Students**

Table 4 displays the descriptive statistics for the success gaps between White and Hispanic/Latinx students for control and treatment institutions for the pre-OENC year and the OENC implementation year.

**Table 4**

*Descriptive Statistics for White and Hispanic/Latinx Students' Success*

| Statistic | Pre-OENC Year | | OENC Implementation Year | |
|---|---|---|---|---|
| | White—Hispanic / Latinx Control (*n*=6) | White—Hispanic / Latinx Treatment (*n*=6) | White—Hispanic / Latinx Control (*n*=6) | White—Hispanic / Latinx Treatment (*n*=6) |
| Mean Gap | 0.50 | 9.00 | 7.67 | 3.83 |
| Standard Deviation Gap | 9.32 | 6.19 | 6.71 | 6.71 |

Pure comparison of the mean gaps for the control group from the pre-OENC year to the OENC implementation year would indicate that the average equity gap for those institutions had increased ($xbar_{Pre\text{-}OENC}$ - $xbar_{implementation}$ = -7.17) whereas the same comparison for the treatment group declined ($xbar_{Pre\text{-}OENC}$ - $xbar_{implementation}$ = 5.17). When the change in gaps was analyzed using a two-sample *t*-test, the difference between the gaps was statistically significant ($t$ =-2.192, $p$ =.05) and the effect of the OENC award was large (Cohen's $d$ =-1.132).

**Success Gaps Between Black/African American and Hispanic/Latinx Students**

Table 5 displays the descriptive statistics for the success gaps between Black/African American and Hispanic/Latinx students for control and treatment institutions for the pre-OENC year and the OENC implementation year.

**Table 5**

*Descriptive Statistics for Black/African American and Hispanic/Latinx Students' Success*

| Statistic | Pre-OENC Year | | OENC Implementation Year | |
|---|---|---|---|---|
| | Black/African American—Hispanic/Latinx Control (*n*=5) | Black/African American—Hispanic/Latinx Treatment (*n*=5) | Black/African American—Hispanic/Latinx Control (*n*=5) | Black/African American—Hispanic/Latinx Treatment (*n*=5) |
| Mean Gap | -9.10 | 3.90 | -16.80 | -12.90 |
| Standard Deviation Gap | 11.80 | 7.62 | 11.64 | 6.15 |

Pure comparison of the mean gaps for the control group from the pre-OENC year to the OENC implementation year would indicate that the average gap between Black/African American and Hispanic/Latinx students for those institutions had increased ($xbar_{Pre\text{-}OENC}$ - $xbar_{implementation}$ = 7.70) while the same comparison for the treatment group also increased but by a greater magnitude ($xbar_{Pre\text{-}OENC}$ - $xbar_{implementation}$ = 16.80). When the change in gaps was analyzed using a two-sample *t*-test, the difference between the gaps was statistically significant ($t$ =-2.343, $p$ =.05) and the effect of the OENC award on the average gap was large (Cohen's $d$ =-1.482).

## Discussion and Conclusions

Overall, this study indicates that institutions that employed faculty who received an OENC grant requiring the implementation and application of open resources experienced significant declines in equity success gaps between White and non-White students enrolled in introductory biology coursework. Although the magnitude of the change in the gap varied between comparisons of White students and Black/African American or Hispanic/Latinx students, all comparisons between White and non-White students exhibited large effect sizes. This finding is consistent with work by Colvard and Watson (2018) and Shaw et al. (2019) supporting the use of open resources in reducing equity gaps and in application for STEM coursework.

The implications for these findings are vast in that although implementation of open resources—as evidenced in these findings and the work of others (Colvard & Watson, 2018; Shaw et al., 2019)—seems to improve student success for students regardless of race/ethnicity, there were different impacts aligned to the race/ethnicity observed. Institutions, faculty, and systems may find success in decreasing success gaps within their populations by exploring the use of OER in the STEM curricula. Furthermore, although OER implementation is not a panacea for student success gaps, it is a reasonably inexpensive approach to addressing equity issues at both the institutional level and at the classroom level. Furthermore, OER could be adopted piecemeal for instructors as they transition from traditional course resources, with the goal of using all OER after a set amount of time.

Another noteworthy finding from the results of this study is the change in the success gap between the two observed non-White groups. Unlike comparisons between White and non-White students, the success gap between Black/African American and Hispanic/Latinx students appeared to grow in favor of Hispanic/Latinx students with institutions that employed faculty who were recipients of OENC grants. Although there are many potential implications of this finding, one might conclude that the OENC grant, although benefiting all students, disproportionately aided the success of Hispanic/Latinx students over all other measured groups. This finding supports the work of other researchers who have identified disadvantages experienced by Hispanic/Latinx students (Krogstad, 2016; Schneider et al., 2006) and the potential for open resources in aiding in student success through the alleviation of certain financial burdens disproportionally experienced by these students.

## Limitations

This study was limited by several factors. The first is related to the use of the OENC grant as a proxy for student success as a result of open resources. Recipients of the OENC grant were incentivized to implement open resources in their courses. Gritz (2004) argued that providing incentives prior to requirement of a task, as was the case in the OENC grant, resulted in better response and quality of work. Adopting open resources is a complicated endeavor and even more so if done voluntarily. Readers of this study should be cautious in attempting to separate the financial incentive of participation from the impact of open resources alone.

Second, the sampling frame for both treatment and control groups was limited to two-year public institutions in North Carolina. All courses observed were introductory biology courses that all applied common topics from a statewide set of course descriptions. Any attempt to generalize these findings to other coursework, states, or systems of higher education is not recommended.

Finally, this study examined the gap in the percentage of successful students at institutions disaggregated by their self-reported race/ethnicity. There was no attempt to account for student achievement measured by grades, test scores, or other academic characteristics beyond successful attempts in the course examined. Examination of academic achievement as a result of either the OENC grant or other implementation of open resources remains an area for further research.

## Areas for Further Research

The investigation presented here focused on the impact of OER on historically underrepresented students within one specific STEM course: introductory biology. Future investigations should look within other STEM related courses in order to compare findings of this study with other courses where OER is being implemented (i.e., chemistry, physics, etc.). The impact of incentivizing faculty members for OER implementation could also produce a litany of information relating to the opportunities of funding faculty-led authorship in courses which do not currently have OER available. Addressed within the limitations of this study was the fact that it focused on two-year community college students. Future research is needed to investigate the impact across institutions, such as universities, and how OER impacts historically underrepresented groups across those institutions. Additional insight could be gained from case studies of the impact of OER on success rates and lived experiences of students, as well as the impact of funding on OER implementation and whether funding provided long term implementation success. Finally, investigating the impact of OER in non-STEM fields or on variables other than course success rates may bring to light other ways in which lowering the barrier to access can impact teaching and learning for all.

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