

Modeling the Impact of a Critical Mass of Non-White Teachers on College Retention Rates

The University of Chicago

M.A. Program in Computational Social Science

MACS30200 – Perspectives in Computational Research

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June 6, 2018

Abstract

The gap in educational outcomes between white and non-white, but especially black and brown, students remains a persistent problem. In measurements ranging from standardized test-scores to college-going rates to discipline rates, white students disproportionately perform better than their black and brown peers. Using publicly-available data from Chicago Public Schools (CPS), this paper examines the impact on a given high school's graduate class's college retention rates from the number of non-white teachers at that high school. While literature suggests that achieving a "critical mass" of roughly 30% of non-white teacher at a school would result in better student performance, i.e. college retention rates, this paper's findings on 71 public and charter schools in the CPS system using OLS regression, linear spline, and cubic splines are inconclusive. Further studies are necessary to pinpoint the relationship between a critical mass of non-white teachers and college retention rates.

Introduction:

From Equal Opportunity Employment to affirmative action policies to mission statements committed to hiring a diverse workforce, diversity of race and gender in social, political, and economic spaces and organizations is often either mandated to a certain extent or desired. While the policies mandating specific thresholds of diversity or advocating race-conscious admissions policies have come under fire in recent decades, i.e. *Regents of University of California vs. Bakke* (1978), *Grutter vs. Bollinger* (2003), *Fisher vs. University of Texas* (2013), this does not diminish the fact that the United States is becoming increasingly diverse. In particular, young people in the United States are among the most diverse group of people in the history of this country. This paper will look into a particular implication of this diversity.

As the student population of American schools becomes increasingly diverse, the demographics of America's teachers have not followed suit. In fact, the racial demographic gap between teachers and students has increased. With greater numbers of non-white students each year, nearly every single state in the U.S. has disproportionate numbers of white teachers leading its classrooms. Although roughly $\frac{1}{2}$ of students in the United States are non-white, the number of non-white teachers in the workforce has stagnated at roughly 20%. Perhaps even more concerning is the decline in the numbers of African-American teachers (Boser 2014; Grissom, Kern, Rodriguez 2015, 190). Perhaps this disproportion would not be as troubling if educational attainment gap between socio-demographic groups of students did not remain as intractable and large as they are today; and especially so for black and brown students.

Among often studied metrics of educational attainment and success include college retention and persistence rates – the endogenous or dependent variable of our research question. Specifically, our research question of interest lies in applying critical mass theory to examine the impact of teacher and administrator racial diversity at the secondary level on college retention and persistence

rates. The subsequent paragraphs will define critical mass theory, review the research behind critical mass theory, cover major studies on college retention and persistence rates, and discuss the connection our research will make between these two fields.

Critical Mass Theory

The idea of a ‘critical mass’ is grounded in the argument that institutional bureaucracies should be demographically representative of the constituents they serve in order to best meet the needs of each social class (Kingsley 1944). In her work focusing on gender representation on teams, Kanter introduces critical mass theory to argue that gender diversity below a threshold of 35% is ineffectual in enhancing team performance because minority members are largely reduced to symbolic representatives, or tokens, of specific social group (1977). The power of the critical mass lies in its solidarity, as “minority members are potentially allies, can form coalitions, and can affect the culture of the group” (Kanter 1977, 206). Put simply in the context of this paper, we seek to understand the extent to which a critical mass of non-white teachers at a given secondary school impacts the college retention rates of graduates from that same secondary school. Since then, numerous studies have applied critical mass theory to racial representation and diversity within the field of education – this will be discussed in the following paragraphs.

Importance of Student-Teacher Racial Matching

The full spectrum of ways in which teachers, who share the racial background as their students, positively impact these students is well-documented. Studies applying representative bureaucracy consider teachers as “street-level bureaucrats” and their students as “clients” (Grissom, Kern, Rodriguez 2015, 186). Moving forward we will forgo utilizing this terminology and simply refer to educators and the youth they teach as teachers and students.

In terms of empathy, shared backgrounds between non-white teachers and students may facilitate better communication and help non-white teachers more effectively identify the supports a

student needs (Grissom, Kern, Rodriguez 2015, 187). Non-white students may also be more inclined to exert great effort and investment in their schooling for a fellow non-white teacher they view as a role model (Dee 2005, 159; Grissom, Kern, Rodriguez 2015, 187, Cole 1986, 332).

Studies have also uncovered the discretionary power that teachers exert over students of color, but especially black and brown students, when it comes to special education services or gifted program assignment. An observed, “negative association between the proportion of minority teachers and the proportion of minority students in special education” is present (Grissom, Kern, Rodriguez 2015, 188). Fraga, et al. showed that Hispanic students are less likely to be assigned to special education in the presence of larger numbers of Hispanic teachers (1986). On the other end of the spectrum, black students are observed to be three times more likely to be assigned to gifted programs by black teachers than non-black teachers (Grissom & Redding 2016, 10). Evidence has also shown that a critical mass of 20-40% of teachers who are black or Hispanic is required to see a noticeable increase in the number of black and Hispanic students enrolled in talented and gifted programs (Grissom, Rodriguez, Kern 2017; Nicholson-Crotty, Grissom, Nicholson-Crotty 2011, 591). This demonstrates the wide gulf in expectations that teachers, particularly white teachers, hold between white students and non-white students (Papageorge et al. 2016). This divergence has been shown to further manifest at the classroom-level with implications for student achievement in the future, as it pertains to college-going and retention rates.

Case studies have also shown that as percentage of black teachers increase, the disproportionate discipline of black students decreases; this holds especially true for in-school-suspensions and expulsions (Meier & Stewart 1992). When there is racial mismatch between teacher and student, there is a higher chance of the student being viewed as inattentive or sub-par in their work completion rates (Dee 2005, 162-163). These unintentional and unconscious biases in teachers manifest themselves with insidious consequences. Concrete differences in student outcomes, such as

lower drop-outs rates in high school, higher graduation examination passage rates, and higher scores on standardized tests have been observed when teacher representation matches that of students (Pitts 2007, 514; 517; Meier & Stewart 1992, 166). This thus informs the necessity of further studying the long-term consequences of achieving a critical mass of racially diverse teachers. With the scope of research predominately focused on the K-12 years, we must also look towards post-secondary year of education to examine the impact of critical mass on college retention and persistence rates.

Factors Impacting College Retention Rates

Recent research into the factors affecting college retention and persistence rates often cite Tinto's 1975 interactionist argument that both academic integration and social integration matter in determining college retention rates. Tinto's widely cited claim is that drop-outs result from "insufficient interactions with others in the college and insufficient congruency with the prevailing value patterns of the college collectivity" (1975, 92). While this argument continues to be widely accepted, other researchers have built off of Tinto's work to study other factors – both individual and institutional – that impact college retention and persistence rates.

Reason (2003) cites Astin, Korn, & Green among the many studies that have shown variables such as high school grade point average (GPA) and college admissions test scores (SAT/ACT) as consistent predictors of retention (Astin, Korn, & Green 1987; Reason 2003). Yet, we know from previously cited studies that teacher demographics and diversity have clear impacts on student achievement and test scores, which highlight the need to further examine this critical mass theory.

In a similar vein, black male student assignment to black teachers in at least one grade between the 3rd and 5th grade has been shown to reduce the chances of high school drop outs in these students as well as increase the likelihood of college attendance (Gerchenson et al. 2017).

Specifically, the probability of dropping-out for these students is lowered by 39% and the expressed intent to attend college increased by 29% among the black male students in the study (2-3; 35). Such findings open up other avenues to study the long-run impact of teacher diversity on educational outcomes.

The purpose of this research paper is to provide a previously unmade connection between these two broad and important fields. Understanding that non-white teachers may play an outsize role in impacting academic outcomes for students, but especially non-white students, we will examine whether this impact extends to college retention rates. We take on a previously constructed model hypothesizing the nonlinear relationship between “representative bureaucracy” and “student outcomes” using critical mass theory (Meier, Wrinkle, Polinard 1999, 1032-1033); and will specify it to predict college retention and persistence rates for public school graduates in Chicago to answer the question of whether a critical mass of non-white teachers at a school be used to predict an observable difference of that school’s college-going graduates to remain enrolled after their first year.

Operationalizing Theoretical Constructs & Defining the Model

As previously mentioned, the purpose of this research paper is to connect two important nodes in the field of education. Scholarship on college retention and persistence rates has extensively studied student demographic, student academic, and tertiary institution characteristics as factors that impact retention and persistence rates. Relatedly, but never explicitly connected with this scholarship, is the broad field of work documenting the differentiating treatment and impact white versus non-white teachers have on students. Thus, the model this paper defines hinges on a variable of interest we will call *critical mass*.

The *critical mass* variable takes on a value between 0 and 1 and represents a percentage of a given Chicago high school’s teaching staff that is predicted to be non-white. Recall that the reason

we are interested in *critical mass* as a variable is rooted in the theory of *representative bureaucracy*. This theory originating from Kingsley argues that institutional bureaucracies should be demographically representative of the constituents they serve in order to best meet their needs. Thus, when a particular “critical mass” threshold of non-white teachers is surpassed at a school, we want to examine whether a significant increase in college retention and persistence rates of graduates of that high school can be observed.

RetentionRate

$$\begin{aligned}
 &= \beta_0 + \beta_1 \textit{CriticalMass} + \beta_2 \textit{ELL} + \beta_3 \textit{SPED} + \beta_4 \textit{FreeLunch} + \beta_5 \textit{White} \\
 &+ \beta_6 \textit{Black} + \beta_7 \textit{NativeAmericanAlaskan} + \beta_8 \textit{Hispanic} + \beta_9 \textit{MultiRace} \\
 &+ \beta_{10} \textit{Asian} + \beta_{11} \textit{HIPI} + \varepsilon
 \end{aligned}$$

The model above illustrates the *critical mass* variable as the variable of interest as well as including a host of demographic control variables. The model will control for: 1) *ELL* as the proportion of a school’s student population that has English Language Learners (or as CPS classifies them as “bilingual”); 2) *SPED* as the proportion of a school’s student population that requires special education services or Individualized Education Plans (IEP); 3) *FreeLunch* as the percentage of students of a school’s student population that qualifies for free or reduced lunch – a socioeconomic signifier for a school; 4) *White*, *Black*, *NativeAmericanAlaska*, *Hispanic*, *MultiRace*, *Asian*, and *HIPI* as the proportion of a school’s student population that are white, African-American, Native American/Alaskan, Hispanic, multiracial, Asian, or Hawaiian/Pacific Islander, respectively.

The dependent variable of interest – *Persistence* – is the percentage of graduates of a specific Chicago high school who returned the college or university after their first year enrolled at a college or university.

Data Source & Collection

The data utilized in this research is publicly available data published by Chicago Public Schools. The [data](#) on school-level demographics of students is published in this data portal under the “Demographics” tab. The [data](#) on college enrollment and persistence is also housed on this data portal. The [data](#) on individual teachers at each individual school is taken from the Employee Position Files, also published and maintained by Chicago Public Schools. These are the raw data files that were used in this research. Data collection process consisted of downloading the excel files and/or csv files from the Chicago Public Schools Data Portal. Further description in the following section details the process of calculating and obtaining the *critical mass* variable from the Employee Position Files.

Data Wrangling & Imputation & Dealing with Missingness

Most of publicly available data published by Chicago Public Schools is granular only down to the school-level. Furthermore, individual school profiles reveal only demographics of the student body, not the teaching staff. Demographics for the teaching staff is available publicly only at the district level, which is not helpful for the purposes of our model. Thus, we use the Employee Position Files which contains individual-level data of every employee on payroll in Chicago Public Schools.

We first filter the dataset by the keyword “teacher” to include only employees who are classified as “teachers” in some capacity by Chicago Public Schools. This yields roughly 21,000 individuals which is slightly larger than the 20,626 teachers the CPS website identifies is on their teaching staff. This discrepancy may be due to the inclusion of individuals who have “teacher” in their job title but are not assigned to a specific school as well as teacher’s assistants. The former inclusion does not impact our variable of interest, *critical mass*, as individuals not directly affiliated with any specific school will not count towards that school’s *critical mass* variable. We choose to

include “teacher’s assistants” as individuals in these positions on occasion will execute instruction, discipline, and other actions similar to classroom teachers.

To obtain our variable of interest, *critical mass*, we use the *ethnicolr* python package to impute the race of a teacher based on either their last name or their full name from the Employee Position Files dataset. The *ethnicolr* package contains multiple methods for imputing race based on either a given last name or full name – we utilize an ensemble of three of these methods to predict race based on a name. Each of these three methods is based on a specific dataset: 1) the 2010 United States Census 2) Wikipedia 3) Florida voter registration files. The first method takes an individual’s last name and predicts their race based on the proportion of individuals in the 2010 U.S. Census that identified as a particular race. The second method utilizes Wikipedia data to predict a specific region of the world (i.e. ‘Greater African, Muslim’ or ‘Greater European, East European’) from which the last name appears and from there, we generalize those regions into broader race categories like “white” or “Asian”. The third method takes an individual’s full name and predicts their race based on the proportion of individuals in Florida’s voter registration files that identify as a particular race. Finally, if two or more of the three methods predicted the same race, then we classified that teacher as that race. Following that process, we then calculated for each school the proportion of teachers at each school that identified as “non-white” versus “white” – that proportion is our *critical mass* variable for each school.

Next, we had to solve issues with missingness in our dependent variable – *persistence*. There are 5 years of enrollment and persistence rates for each high school in the dataset. If a school has 2 or fewer years of missing data, the enrollment and persistence rates are imputed from the average of the 3 years for which the school does have data. Otherwise, a school with 3 or more years of missing enrollment and persistence rates is dropped from the dataset.

To connect these two data sets, we initially attempted using record linkage to link on school name between the college retention & persistence data set and the critical mass data set. Given two different sets of school identification numbers provided, linking on school ID was not possible. Further, there was relatively large gap in naming conventions native to both datasets. A single school may go by multiple names (e.g. “Hyde Park HS” and “Hyde Park Career Academy” are the same school; “Payton HS” and “Walter Payton College Prep High School” are also the same school). This proved challenging for efficiently measuring the distance between two strings using the *recordlinkage* package in python using Levenshtein, qgram, and Jaro-Winkler methods. Thus, the school names were manually recoded and then merged.

Our final dataset yields a total of 71 high schools in Chicago from which we run our model.

(Note: All code for data cleaning, wrangling, imputation can be found in the *import_data.py* file on Github).

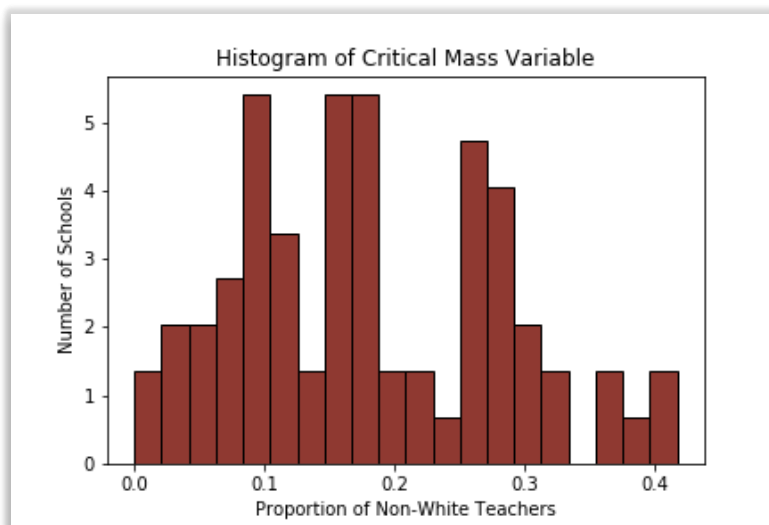
Summary Statistics

<i>Critical Mass Variable</i>	
# Obs.	71
Mean	0.1823
Std. Dev.	0.1019
Min.	0.0000
25%	0.1033
50%	0.1728
75%	0.2670
Max.	0.4167

Critical Mass & Retention/Persistence Rate Variables

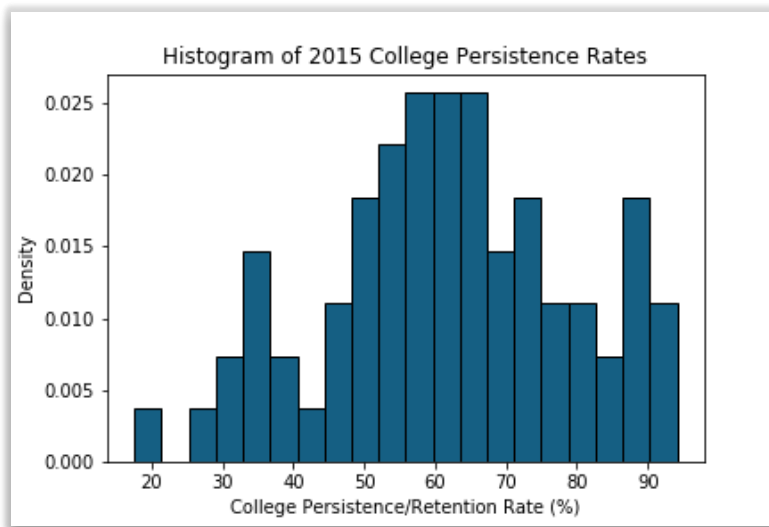
The distribution of our variable of interest *critical mass* is plotted in the histogram below in *Figure 1*. We observe a multi-modal distribution. Both an interesting and problematic observation of this data for our model is that this distribution of proportion of non-white teachers is more representative of the national demographic of teachers in public schools than of the demographic of teachers in Chicago Public Schools. CPS reports that ~50% of its teachers are not white. Given the base dataset used by the *ethnicolr* package utilizes nationally representative populations of names, this is perhaps unsurprising.

Figure 1:



The distribution of our dependent variable *Persistence* (aka retention rates) for the year 2015 is plotted in the histogram below. We see a trend that is skewed slightly to the left with the median of high school's having graduates persisting at 61.4%.

Figure 2:



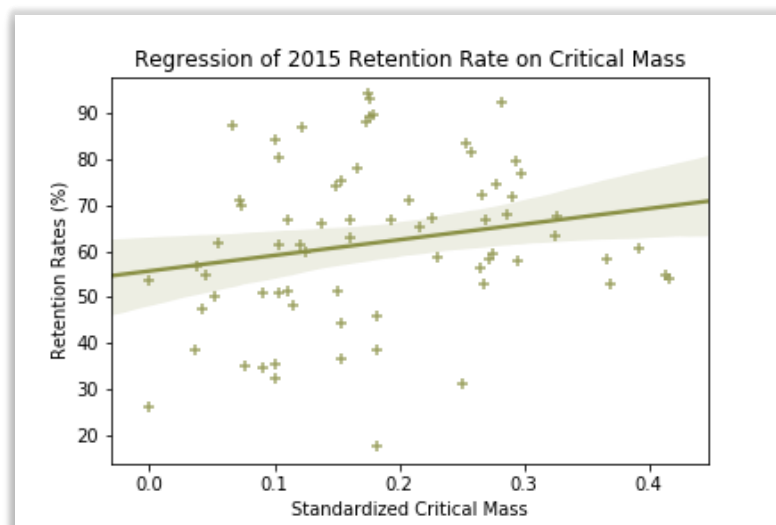
Regression & Spline

After running OLS regression on college persistence data from the year 2015, the reported estimates are in *Table 1*, below. While we have a relatively high R-squared value, which signals the proportion of variation in retention rates that is explained by this model, our variable of interest *critical mass* has neither the sign in the direction the literature might suggest. Furthermore, *critical mass* is not significant in this particular model. We can plot the relationship between *critical mass* and *persistence* for years in which we have data 2010-2015 below and run an OLS regression observed in *Figure 3*.

Table 1:

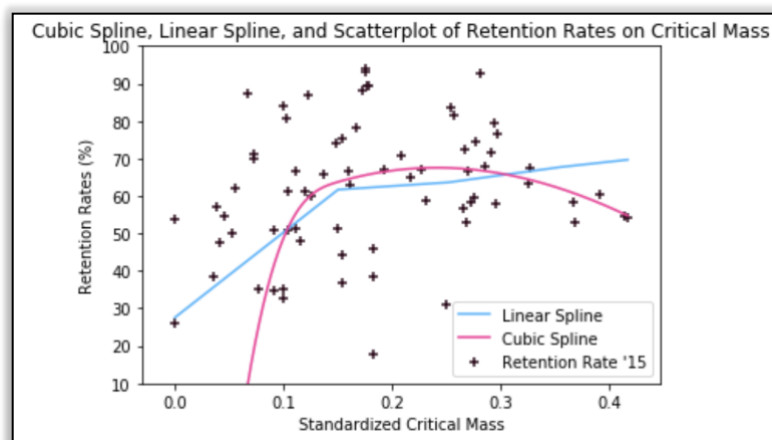
Ordinary Least Squares Regression			
R-Squared	0.708		
Adjusted R-Squared	0.648		
Variable	Coeff. Est.	St.Err.	P-Value
<i>Intercept</i>	70.1730	2902.180	0.981
<i>Critical Mass</i>	-19.522	22.049	0.380
<i>White</i>	0.7278	29.005	0.980
<i>Black</i>	0.6698	29.021	0.982
<i>Native Am/Alask</i>	0.1416	29.549	0.996
<i>Hispanic</i>	0.8030	29.019	0.998
<i>Multi-racial</i>	-3.8293	29.569	0.897
<i>Asian</i>	1.2574	28.972	0.966
<i>Hawaiian/P.Island</i>	-1.1538	30.553	0.970
<i>Unknown</i>	-0.5121	29.497	0.986
<i>ELL</i>	0.1835	0.590	0.757
<i>SPED</i>	-63.539	19.516	0.002
<i>Free Lunch</i>	-72.695	26.834	0.009

Figure 3:



From the plots above, there appears to be no conclusive or consistent relationship between *critical mass* and college *retention/persistence* rates. While the literature signaled that we might reasonably hypothesize that the relationship between *critical mass* and *persistence* would be non-linear, we do not observe any clear or evidence “threshold” of *critical mass* at which *persistence* noticeably shifts, increases, decreases, etc. when running the OLS regression. Nonetheless, we continued to model both a linear spline and cubic spline on the data and our results are displayed in *Figure 4* below.

Figure 4:



The linear spline shows a positive correlation between *critical mass* and *retention rates*. That being said, the slope of the correlation may be positive, but the magnitude of the slope does not align with our hypothesis. In accordance with available literature, we hypothesized that the slope would increase in positive magnitude upon reaching a critical mass threshold of roughly 0.3 or 30% of staff in a given secondary school. As we can see in *Figure 3*, there is a clear change in slope around 0.15, after which increasing levels of *critical mass* are correlated with minimal increases in *retention rates*. We see similar results upon instituting a cubic spline; and in fact, above a threshold of 0.3, we actually observe the opposite relationship of what we would expect at that level of critical mass.

At this point, it may be necessary to revisit the race imputation process given the underestimation of the number of non-white teachers in Chicago Public Schools by our process. This will be discussed further in following sections.

Discussion & Revisiting Methods

Recall, that our hypothesis was that upon reaching a particular threshold of non-white teachers in a secondary school, i.e. reaching a “critical-mass” of non-white teachers on a staff, that we would expect to see a significant uptick in college retention rates of graduates from that particular secondary school. Based on data from SY2015-2016 in Chicago Public Schools, this model did not find results to support that hypothesis. There are several likely reasons to account for this particular result.

To address some of the weaknesses in calculating our *critical mass* variable: As observed in the summary statistics table for *critical mass*, the mean proportion of non-white teachers at each high school that we obtain is roughly 18% of the teaching staff. Thus, there is heavy underestimation from our imputation method of non-white teachers in sample given that it is reported that 50% of teachers in Chicago Public Schools are non-white. Although, interestingly enough, our race imputation methods align almost exactly with national trends where roughly 18% of teachers are not-white on a national level. This could be the datasets on which the *ethnicolr* package draws to make predictions of race based on name; those datasets – the U.S. Census, Wikipedia, and Florida voter registration rolls – are not representative of the population of Chicago. Although, the predictions from the Florida dataset produced the closest aggregate predictions to total number of non-white teachers of our dataset. Moving forward, it would obviously be beneficial to obtain school-level data on teacher and administrator demographics as this would make our critical mass variable a much less biased variable.

Secondly, in alignment with critical mass theory literature, we attempted both a linear and cubic spline. The literature suggests both a non-linear relationship and that around 30-50% of non-white people in an organization (teachers at a school) and noticeable difference in outcome (retention/persistence rate) may be observed. Given the underestimation of non-white teachers in calculating our *critical mass* variable, we lacked the necessary number of observations that had a *retention rate* over 0.3.

Of course, we would caution against reading too far into the results found when running OLS Regression as well as both the linear and cubic spline given that the high level of insignificance of our coefficients. Furthermore, had the findings been significant, they would run counter to numerous studies both quantitative and qualitative that found substantial benefits to higher levels of non-white teachers employed in a particular school. Finally, at the most micro-level of the classroom, numerous studies have shown that disproportionate numbers of white teachers have had problematic consequences including: implementing disproportionate punishments on black and brown students and holding below-average expectations for black and brown students. We would maintain that such discrepancies in individual teacher practice have systemic implications. They have systemic implications given that the supermajority of educators in the education system today are white.

Thus, the question of the impact of secondary teacher demographics on college retention rates remains unanswered. Future studies examining both the impact of critical mass on various aspects of the education system, not just college retention rates, are necessary. Future steps into answering this question of the impact of critical mass of student outcomes should involve obtaining data at the at least the school-level, if not the classroom level. The ability to follow groups and classes of students who have or have not had teachers who match their race would provide greater

potential to answering this question of longer-term impacts of reaching a critical mass of teachers of color in the classroom.

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