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Unraveling the STEM Pipeline: High School Preparation, College Retention, and Racial Disparities

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Abstract

Using a longitudinal nationwide college student dataset along with a quantitative research design, this study examines the link between high school STEM course participation, college STEM major retention, and racial disparities. Specifically, we investigate how high school STEM course participation impacts college STEM major retention and identify racial differences in high school STEM course enrollment and college STEM retention. Our findings show that students who engaged in more rigorous high school STEM coursework, particularly in Physics and Chemistry, are more likely to stay in their STEM majors in college. We also found that this relationship is moderated by students' racial background. Results show that Asian American students demonstrated the highest retention rates in their STEM majors compared to their White, Latinx, and Black peers. Furthermore, our findings reveal that Asian American and White students tended to complete more years of advanced Physics and Chemistry course in their high school compared to their Black and Latinx counterparts. Overall, this study highlights the need to address racial inequities in STEM education in both high school and college and improve support systems to promote STEM retention across racial groups.

Keywords: STEM Retention, Racial Disparities, High School Coursework, Quantitative Analysis, Educational Equity

1. Introduction

In the United States, almost 50% of students who declare a STEM major at their college entry leave their STEM majors before their graduation. This high rate of STEM attrition is concerning because it impacts the ability of our country to remain competitive in the growing international labor market, which demands an increasing number of STEM professionals. Low STEM retention rates are even mor concerning as it comes to racial equity. Research has shown that underrepresented racial minorities including Black, Latinx, and Native American students are more likely to leave their STEM college majors than their White and Asian Peers (Chang et al, 2011). Many studies have also indicated that students' academic preparation prior to their college entry is associated with their retention in STEM undergraduate majors (Chen, 2013).

To explore the dynamics of STEM major retention and racial disparities, our study employs a quantitative research design utilizing longitudinal, nationwide educational data. Through statistical analyses, we aim to elucidate the associations between students' high school STEM course participation, college major retention, and racial background. Specifically, we will examine the impact of variables such as the duration and intensity of high school STEM coursework on students' likelihood of persisting in STEM majors through college. Additionally, we will examine demographic trends in high school STEM course enrollment and college major retention across racial groups, employing rigorous quantitative methods to identify patterns and disparities.

Consequently, in this study, we examine the relationship between students' years of high school study in STEM courses and their retention in STEM college majors, racial differences in high school STEM courses taken, and racial differences in college STEM retention. Specifically, we seek to answer the following research questions: (1) What high school STEM courses are related to the retention in STEM college majors? (2) How does the retention in STEM college majors differ by students' racial background? (3) How do the high school STEM courses taken differ by students' racial background?

2. Literature Review

2.1 STEM Retention in College

As STEM workforce becomes a more pivotal factor in national economic growth, there is an increasing attention and concerns on college students' retention in STEM academic majors. While the institutions and government have invested on diverse interventions and initiatives to improve the STEM retention rate in college, many challenges and issues pertaining to STEM college education persist.

Among others, the rigorous nature of STEM curricula is one of the main factors impacting college students' STEM retention. STEM programs are notoriously known for their challenging coursework, particularly due to their requirements of mathematics and science courses (Seymour & Hewitt, 1997). Studies showed that this rigorous nature of STEM curricula significantly affects higher dropout rates in the fields. For example, Freeman and their associates (2014) found that instructors in STEM fields tend to heavily use lecture-based

teaching approaches, and these teaching methods often neglect student engagement and unique learning needs of students resulting in higher dropout rates. Similarly, Chemers and their associates (2011) argue that the competitive and isolating environment of STEM fields negatively affect STEM college students' sense of belonging and self-confidence, increasing the likelihood of dropout.

Lack of support systems is another factor exacerbating STEM retention in college. While the effectiveness of support systems plays an important role in STEM college retention, many institutions do not have sufficient resources to create effective support systems to address diverse needs of their STEM students. Studies showed that lack of appropriate academic advising and mentorship seems to adversely affect STEM students' retention (Hunter et al., 2007). In contrast, Zhao and Kuh (2004) found that effective support systems such as peer mentoring and tutoring are positively related to higher retention rates among STEM students.

Financial concerns and lower psychological well-being also contribute to lower STEM retention rates in college. Research showed that STEM students financial concerns may negatively affect their academic performance, leading to higher dropout rates (Moore et al., 2021; Joo et al, 2008). Furthermore, issues related to psychological well-being also affect STEM students' retention. The high stress coupled with demanding nature of STEM curriculum may negatively affect STEM students' psychological well-being, which may lead to lower academic performance and higher dropout rates (Beiter et al., 2015; Misra & Castillo, 2004).

2.2 STEM Retention and Race

The lower college STEM retention rates are particularly concerning when it comes to underrepresented racial minority groups, including Black, Latinx, and Native American students. Despite various initiatives and programs to promote STEM retention rates for underrepresented racial and ethnic groups, these students experience unique challenges and obstacles in their STEM college education that affect their academic success and retention in STEM programs.

Underrepresented racial minority students in STEM fields often experience stereotype threat. Steele & Aronson (1995) define stereotype threat as a psychological phenomenon where individuals fear reinforcing negative stereotypes about their racial or ethnic groups. A study found that STEM students' perception of stereotype threat tended to decrease their self-confidence, resulting in higher likelihood of dropout (Cheryan et al, 2017).

This population also often experiences underrepresentation and a lack of role models in STEM academic majors. The underrepresentation and the absence of mentors lower their academic and social self-efficacy, which adversely affects their retention rates (Eagan et al., 2013; Kricorian et al., 2020). Additionally, economic inequities also significantly impact racial gaps in STEM retention. Joo and their associate (2008) argue that STEM students from underrepresented racial groups are more likely to experience financial difficulties and these

challenges negatively affect their academic engagement and performance, reducing their likelihood of STEM retention.

2.3 High School STEM Courses and College Retention

Research has well documented that high school STEM courses significantly affect STEM students' college retention. Research showed that students who took more advanced STEM courses in their high school, such as Advanced Placement (AP) or International Baccalaureate (IB) programs, tended to stay in their college STEM majors compared to their peers who did not or did so less (Wang & Degol, 2013, 2024).

Studies also showed that the quality of high school STEM courses is meaningly associated with college students' STEM retention. Tai (2006) found that students who received high-quality STEM education (e.g., active learning, real-world application) in their high school were more likely to stay in their college STEM majors. Similarly, Sadler et al. (2014) suggest high-quality STEM curricular in high school positively affects not only students' academic preparedness, but also their long-term retention in their college majors.

3. Methods

3.1 Data Source and Sample

We use data from the National Longitudinal Study of Freshmen (NLSF). The NLSF is a multi-wave longitudinal survey of 3,864 students from 28 institutions. The survey was administered to students in waves at five different time points and gathered extensive information on students' college experiences. For this study, the sample is limited to students who declared a STEM major at college entry. The final analytic sample of the study consisted of 755 STEM undergraduates across 28 institutions. The racial composition of the sample is as follows: 191 (25.3%) White, 204 (27.0%) Black, 169 (22.4%) Latino/a, and 191 (25.3%) Asian American students.

3.2 Variables and Analysis

The dependent variable for the first and second research questions was students' retention in STEM undergraduate majors, and it was measured by a dichotomous variable that indicates whether a student who declared a STEM major at the entry of college stayed in a STEM major at the end of the third or fourth college year. The independent variable for the first research question was students' years of high school study in STEM courses whereas the independent variable for the second research question was students' racial background. For the third research question, the dependent variables were students' years of study in high school STEM courses while the independent variable was students' racial background. We used crosstabulations with chi-square tests for the data analysis.

4. Results

4.1 The Relationship between Duration of High School STEM Courses and College STEM Retention

Our findings demonstrated that STEM undergraduate students who took more Physics and Chemistry courses in their high school tended to be more likely to stay in STEM majors in their college years compared to their peers who did not or did so less (see Table 1). The crosstabulation results showed that 70.3% of STEM freshman students who took Physics courses for 3 to 4 years in their high school stayed in their STEM college majors in their junior or senior year, while 54.5% of their peers who took the high school Physics courses for 1 to 2 years and 29.9% of their peers who did not take the high school Physics course did so ($\chi^2 = 38.34$, $p < .001$). Similarly, our results indicated that 67.3% of STEM freshman students who took Chemistry courses for 3 to 4 years in their high school stayed in their STEM college majors in their junior or senior year, while 48.7% of their peers who took the high school Chemistry courses for 1 to 2 years and 25.0% of their peers who did not take the high school Physics course did so ($\chi^2 = 29.10$, $p < .001$).

Table 1. College STEM Retention Rates by the Duration of High School STEM Courses

High School Courses Taken	College STEM Retention Rates			
	0 years	1-2 years	3-4 years	
Chemistry	25.0%	48.7%	67.3%	$\chi^2 = 29.10$, $p < .001$
Physics	29.9%	54.5%	70.3%	$\chi^2 = 38.34$, $p < .001$
Biology	66.7%	50.8%	59.6%	$\chi^2 = 6.75$, $p < .05$

4.2 Racial Differences in College STEM Retention

Our findings indicated that there are significant racial differences in terms of college STEM retention (refer to Table 2). Results showed that Asian American undergraduate students reported the highest retention rate in their STEM majors (72.1%), followed by White (58.9%), Latinx (56.8%), and Black students (51.4%; $\chi^2 = 13.51$, $p < .01$).

Table 2. College STEM Retention Rates by Student Race

Race	Retained STEM	Left STEM	Significance Test
Asian	72.1%	27.9%	$\chi^2 = 13.51$, $p < .01$
Black	51.4%	48.6%	
Latinx	56.8%	43.2%	
White	58.9%	41.1%	

4.3 Racial Differences in High School STEM Courses Taken

Our finding demonstrated that there are significant racial differences in the years of study in high school STEM courses (see Table 3). Results showed that Asian American and White students tend to take more Physics and Chemistry courses in their high school compared to

their Black and Latinx peers. Results demonstrated that 23.8% of Asian American and 22.2% of White STEM undergraduate students took Physics courses for three to four years in their high school whereas 11.4% of Black and 15.0% of Latinx students did so ($\chi^2 = 41.01$, $p < .001$). Similarly, results indicated that 45.9% of Asian American and 38.1% of White STEM undergraduate students took high school Physics courses for three to four years whereas 22.4% of Black and 23.4% of Latinx students did so ($\chi^2 = 46.82$, $p < .001$).

Table 3. Percentage of Students who Took High School STEM Courses for Three to Four Years by Student Race

High School Courses Taken	Student Race				
	Asian	Black	Hispanic	White	Significance Test
Chemistry	45.9%	22.4%	23.4%	38.1%	$\chi^2 = 46.82$, $p < .001$
Physics	23.8%	11.4%	15.0%	22.2%	$\chi^2 = 41.01$, $p < .001$
Biology	45.9%	35.7%	31.3%	34.1%	$\chi^2 = 15.08$, $p < .05$

5. Discussion and Implications

Overall findings suggest that students' years of study in high school STEM courses are significantly related to their retention in college STEM majors. Particularly, our findings suggest that students' years of high school study in Physics and Chemistry play an important role in retaining STEM undergraduate students in their majors. We also found that there are racial inequities in both college STEM retention and high school STEM courses taken. Our findings showed that Black and Latinx STEM undergraduate students tend to leave their STEM majors at higher rates, and they also tend to take less high school Physics and Chemistry courses than their Asian American and White peers.

Our findings offer several significant implications, both theoretical and practical. The findings of this study highlight the importance of educational resilience for college students' success. Educational resilience theory suggests that students who experience effective educational practices tend to more effectively overcome academic challenges and engage in their education (Coatsworth, 1998). Jowkar and their associate (2004) also argues that fostering educational resilience positively affects students' persistence and retention in their educational program. Our findings showed that students who took Physics and Chemistry for more years are more likely to stay in their STEM majors in college. These findings provide evidence to support for educational resilience theory.

The racial disparities observed in this study regarding high school STEM course participation and college STEM retention rates also demonstrate that we need to address educational equity issues appropriate within the context of STEM education. We found that Black and Latinx STEM undergraduate students tend to leave their STEM majors at higher rates, and they also tend to take less high school Physics and Chemistry courses than their Asian American and White peers. These findings highlight that existing educational equity theory

should address a more nuanced explanation of the link between high school preparedness and long-term educational success.

In a practical sense, the findings from this study demonstrate that we need to improve the quality of high school STEM curricula in order to enhance college STEM retention rates. Our findings showed that there is a significant relationship between the duration of high school Physics and Chemistry courses and STEM retention during college. These findings suggest that policy makers and educational leaders should make an effort to increase access to the diverse and quality advanced STEM courses in high schools. Diversifying AP and IB STEM course offerings, integrating real-world application into STEM courses, and providing professional development for STEM instructors could be some ways to improve the quantity and quality of high school STEM courses.

Lastly, the racial disparities found in this study regarding high school STEM course participation and college STEM retention point out the need for developing support system to underrepresented students in high schools as well as colleges. High schools and colleges need to facilitate educational environments where underrepresented students can have access to high-quality STEM education. Some possible programs could include peer mentoring programs, after-school interventions, and summer enrichment programs targeted to this population. One example to improve high school STEM curriculum among underrepresented high school students would be implementing early intervention programs such as Project Lead The Way, Upward Bound, and TRIO STEM Programs. These programs will facilitate a richer higher school STEM education to underrepresented students by providing enrichment opportunities and hands-on experiences from an early stage.

6. Conclusion

Our study highlights the importance of high school STEM coursework impacting students' college student retention in STEM majors. The study also shows that extended exposure to Physics and Chemistry positively affects college students' STEM retention rates. Furthermore, the findings also uncovered racial disparities in the participation in high school STEM courses as well as college STEM retention rates. Consequently, the findings of the study suggest that secondary and postsecondary education should strive not only to strengthen the STEM high school courses but also to improve the racial equity in high school STEM courses taken by students.

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