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Abstract

This study examines the impact of early Algebra I coursework on advanced Carnegie credits among 12th graders from diverse racial/ethnic backgrounds, using data from the NCES HSTS (1990-2019). Findings indicate that early Algebra students, particularly Black and Latinx, earn more advanced credits, revealing a widening gap in advanced course attainment. The study underscores the importance of early Algebra in college readiness and STEM preparation, highlighting the need for interventions to address educational disparities. Future research should explore additional factors influencing college readiness.

Introduction

Taking Algebra in middle school positively benefits students' high school mathematics achievement and mathematics attainment (Edosomwan et al., 2022; Lee & Mao, 2021; Rickles, 2013). Moreover, increased mathematics attainment has positive long-term effects, such as a higher likelihood of lucrative Science, Technology, Engineering, and Mathematics (STEM) careers, less likelihood of needing public assistance, more prestigious college admissions, and higher lifetime earnings (Adzima, 2020; Battey, 2013; Bohrnstedt et al., 2023; Bressoud, 2021; Rose & Betts, 2004). Unfortunately, tracking policies that place students in course pathways that do not lead to advanced mathematics coursework harms students (Berry & Larson, 2019). While more students from diverse backgrounds continue to enter advanced courses, racial and socioeconomic gaps remain in who takes those courses (Klugman, 2013; Rodriguez & McGuirre, 2019). Inequities in early Algebra tracking placements have limited entry into those early Algebra tracks for marginalized students, such as Black, Latinx, and low-income students (Cha, 2015; Faulkner et al., 2014; Irizarry, 2021; Morton & Riegle-Crumb, 2019; Patrick et al., 2022). The United States Department of Education (2018) has acknowledged these gaps and how they create leaks in the STEM pipeline for Black and Latinx students who are underrepresented in the 24% of students who take Algebra before high school.

This research is critical in emphasizing the importance of interventions to promote the enrollment of marginalized Black and Latinx students into early Algebra I for enhanced college readiness and life outcomes. The benefits of taking Algebra I in middle school regarding mathematics attainment and college readiness have been well studied. However, more research must address middle school Algebra 1, the attainment of advanced coursework in high school, and how that relationship has changed over time. Advanced coursework can lead to better college and career choices and labor market outcomes for men and women of all racial/ethnic groups (Giersch, 2018; Jewett & Chen, 2022; Moller & Stearns, 2012). The purpose of this study is to investigate the relationship between early Algebra I and advanced Carnegie credits over the last few decades across racial/ethnic groups in order to expose inequities. We seek to answer the following research questions:

1. What association does taking early Algebra have on the attainment of Carnegie advanced credit by 12th grade for Black, Latinx, Asian American or Pacific Islander, and White students?
2. How has the association with taking early Algebra and attaining Carnegie advanced credit by 12th grade changed from 1990 to 2019 for Black, Latinx, Asian American or Pacific Islander, and White students?

To answer those questions, we will first explore the literature regarding early Algebra I's benefits

for students and disparities in student enrollment. Next, we will explain our theoretical framework of Quantitative Critical Race Theory (QuantCrit). Then, we will use High School Transcript Study Data to take a QuantCrit approach to analyze the relationship between early Algebra course-taking tracks and advanced high school credit attainment. We will visually compare confidence intervals across time and racial/ethnic groups.

Literature Review

Introducing Algebraic concepts to middle school students can have numerous cognitive and educational advantages. Research shows that early exposure to Algebra promotes better problem-solving skills, abstract reasoning, and a deeper understanding of mathematical principles (Baldinger, 2018; Ketterlin-Geller et al., 2019). Students who engage with Algebraic concepts early on tend to perform better in subsequent math courses and standardized assessments. By exploring the documented benefits of early Algebra, we can better understand how it can impact academic achievement and help students pursue advanced mathematical studies. Unfortunately, access and enrollment in Algebra in the middle grades remains an equity issue.

Despite the potential benefits, disparities exist in access to and enrollment in early Algebra courses. Socioeconomic factors, race, and gender have been identified as key contributors to these disparities (Filer & Chang, 2008; Riegle-Crumb, 2006). Students from marginalized communities often face barriers to accessing early Algebra opportunities, leading to an educational equity gap (Hogrebe & Tate, 2017). Investigating the disparities in early Algebra access and enrollment is crucial for addressing social justice issues within the educational system and understanding how these inequities may impact the relationship between early Algebra exposure and advanced academic achievements such as Carnegie credits. In the following sections, we explore the early Algebra debate within the context of access, enrollment, and equity.

The Early Algebra Debate

The historical trajectory of early access to Algebra in middle school has been marked by ongoing debates and discussions regarding the merits and drawbacks of introducing Algebraic concepts at an earlier stage in education. Several arguments support offering Algebra in middle school (i.e., cognitive development, enhanced problem-solving skills, and advanced course preparation). Others refute these claims by citing evidence of concern related to several other factors (i.e., developmental readiness, increased pressure and stress, and the potential to widen the achievement gap). This section reviews these arguments in the context of high school mathematics credit acquisition.

Proponents of early access to Algebra argue that introducing abstract mathematical concepts during the middle school years aligns with the cognitive development of students (Spielhagen, 2015; Stein et al., 2011). Specifically, research suggests that students in this age group can engage in more complex and abstract reasoning, making it an opportune time to introduce Algebraic concepts (Pitta-Pantazi et al., 2020; Maudy et al., 2018). Others suggest that early exposure to Algebra has been linked to improved problem-solving skills. Advocates argue that tackling Algebraic problems early on can contribute to developing analytical thinking, logical reasoning, and the ability to confidently approach mathematical challenges (Kieran et al., 2016; Lee et al., 2018). Supporters also contend that early exposure to Algebra better prepares students for advanced mathematics courses in high school and beyond.

Students with a solid Algebra foundation are more likely to succeed in subsequent math courses and may be better equipped to pursue advanced topics like calculus or statistics (Sadler & Sonnert, 2018). In particular, an early Algebra policy can reduce the relationship between course assignment and student characteristics such as income and race/ethnicity while increasing its relationship to academic skills necessary for advanced high school mathematics (Dougherty et al., 2015). Ultimately, this trend is most aligned with the crux of the present study, which seeks to understand the relationship between early Algebra participation and mathematics credits earned across different ethnic/racial groups.

On the other hand, opponents argue that not all students are developmentally ready for the abstract nature of Algebra in middle school. Some students may benefit more from a gradual progression through mathematical concepts, starting with a strong foundation in arithmetic and gradually moving toward more abstract topics (Kaput et al., 2017; Mason, 2018). Critics

also express concerns about the potential stress and pressure that early exposure to Algebra may place on students. For some, introducing abstract mathematical concepts at a younger age could lead to anxiety and hinder the overall enjoyment of learning mathematics (Quilter & Harper, 1988; Zeidner, 2014). Finally, detractors argue that early Algebra access may exacerbate achievement gaps (Domina et al., 2015; Morton & Riegle-Crumb, 2019; Remillard et al., 2017). Students from disadvantaged backgrounds may face additional challenges in adapting to the abstract nature of Algebra, potentially widening educational disparities.

The discourse surrounding early access to Algebra in middle school involves a nuanced examination of various arguments. While proponents emphasize cognitive development, enhanced problem-solving skills, and preparation for advanced courses, opponents highlight concerns related to developmental readiness, increased pressure, and the potential for widening achievement gaps. Understanding these arguments is crucial for informed decision-making in curriculum development and educational policy regarding the timing of Algebra instruction.

Theoretical Framework

This study takes a Quantitative Critical Race Theory (QuantCrit) approach to data analysis, which considers context and the centrality of racism when approaching data, which does not have a voice without the researchers' interpretation of the research (Gillborn et al., 2018). Considering the previously acknowledged racial differences in access and taking of early Algebra, QuantCrit is a suitable theoretical framework for our analysis. Following the tenets of QuantCrit, instead of *p*-values, we will "use confidence intervals to create a more nuanced and less biased interpretation of the findings" (Van Dusen & Nissen, 2021, p. 2). We analyzed each race individually based on Carter and Hurtado's (2007) recommendation of a comparative group approach based on the different experiences of marginalized racial groups compared to White students since previous research has already made it clear there will be racial differences.

Methods

Data Source

The data used was from National Center for Education Statistics (NCES) High School Transcript Study (HSTS) data from 1990, 2000, 2005, 2009, and 2019, as those were the years where 12th grade transcript data were collected as a part of the National Assessment of Academic Progress (NCES, 2022). The HSTS data are collected from a nationally representative sample of public and private schools participating in the National Assessment of Educational Progress (NAEP). HSTS collects transcripts, background student information, school information, course catalog, and, for non-NAEP schools, information about school, teacher, and home factors. The present study's subset of HSTS data divided students by race/ethnicity when discussing when Algebra was taken (before or during high school) and the mean and standard error of Carnegie advanced credits earned.

Variables

The independent variable was early Algebra course-taking, while the dependent variable was the average amount of advanced Carnegie credits earned for grade 12. We will refer to those who took Algebra before high school as early Algebra students and those who took Algebra during high school as non-early Algebra students. Each racial/ethnic category was analyzed separately. The racial categories included White, Black, Latinx, and Asian American or Pacific Islander (AAPI). To protect the confidentiality of students, groups with a small number of students do not have their data included, and we were unable to analyze those groups. Therefore, we did not include missing, other, American Indian, or Alaska Native because those groups did not have complete data. For this study, we did not include the students who did not take Algebra I as they were outside of the scope of this study, which focuses on the timing of taking Algebra I.

Analysis

To see if early Algebra course-taking affects Carnegie credits earned for each racial/ethnic group, we analyzed the data using confidence intervals (CIs) and their visual representations. As previously stated, QuantCrit researchers have advocated for the use of CIs because they allow

for a more nuanced interpretation of the findings when analyzing marginalized groups with smaller populations when compared to the arbitrary cutoff of p-values for statistical significance (Van Dusen & Nissen, 2021). Additionally, confidence intervals are appropriate measures because the available data were limited to the sample size, means, and standard error of whole groups and not individual results. Because this is using a large representative sample, we could calculate the 95% CIs for average advanced Carnegie credits using the average ($\underline{X}$), standard error (SE), and critical value for α = 0.05 of 1.96 with the formula below:

$$95\%\ CI = \underline{X} \pm (1.96 \times SE)$$

CIs are used for researchers to place lower and upper limits on population parameters (Sapp, 2017). When we say that we are using 95% CIs, we mean our intervals cover 95% of the possible values we would see within the population. Cumming and Finch (2005) encourage the use of visual representations of CIs as error bars to promote a better understanding of the data. After calculating the 95% CI in Excel using the provided formula, we used the R version 4.2.0 package *ggplot2* to plot them graphically by race/ethnicity, with the dots representing the mean and the error bars representing the 95% CIs (Wickham, 2011). When using a visual interpretation, the overlap of half the length of one arm or the error bars that represent CIs can be equated with the traditional statistically significant differences, such as p-values, while being more robust (Cumming, 2009).

Results

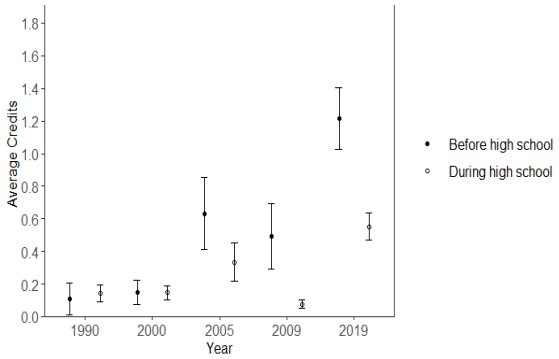
The following section will describe the results using visual comparisons of 95% confidence intervals. See the appendix for the table with all the 95% CIs by year, race, and Algebra track.

Black Student Differences across Tracks and Years

When observing Black student differences between those who took Algebra before compared during high school, there were no significant differences in attained credits in 1990 or 2000 based on the 95% CIs bars. However, in 2009 and 2019, there are significant differences with Black students who took Algebra before high school earning more credits on average. However, there was a less noticeable difference in 2005 based on the slight overlap observed in the confidence bars. It is interesting to note that in 2005, when significant differences became visually apparent, both Algebra tracks attained more average advanced Carnegie credits than either group in 2000, with a statistically significant lack of overlap. In 2009, those who took Algebra during high school earned fewer credits than those who took it during high school in 2005, yet in 2019, those who took Algebra during high school had a statistically significant higher number of advanced credits than in 2009 and 2005. It is also interesting to note that the average credits went down for both groups in 2009 compared to 2005 before jumping back up for both groups in 2009. Black non-early Algebra students had similar average advanced credits earned as early Algebra students in 2005 and 2009, increasing over time even as the gap between Algebra track credits widens.

Figure 1

Black Students Average Advanced Credits by Algebra Track



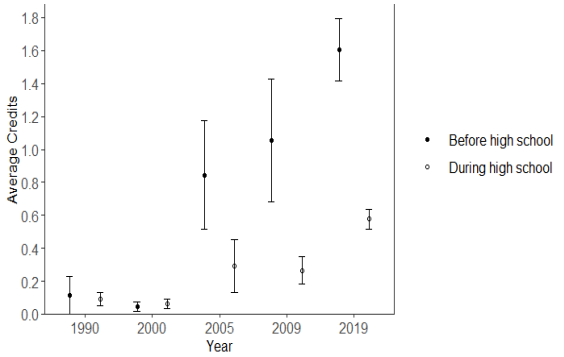
Latinx Student Differences across Tracks and Years

The Latinx student differences in credits earned are very similar to the Black students, with the lack of statistically significant difference in 1990 and 2000 and statistically significant differences starting in 2005 and continuing in 2009 and 2019, with early Algebra students earning more credits than their peers. Once again, in 2005, both Algebra tracks had a statistically significant increase in the number of advanced credits when compared to 2000. While the number of credits for early Algebra increased in 2009 and decreased during high school, neither were statistically significant. There was a statistically significant jump from 2019 to 2009 for early and

non-early Algebra students. Latinx non-early Algebra takers in 2019 had similar average advanced credits earned as early Algebra students in 2005. Even as the gap between Latinx students in the differing Algebra tracks widened each sample year from 2005 to 2019, the overall credits increased for both tracks from 2005 to 2019.

Figure 2

Latinx Students Average Advanced Credits by Algebra Track

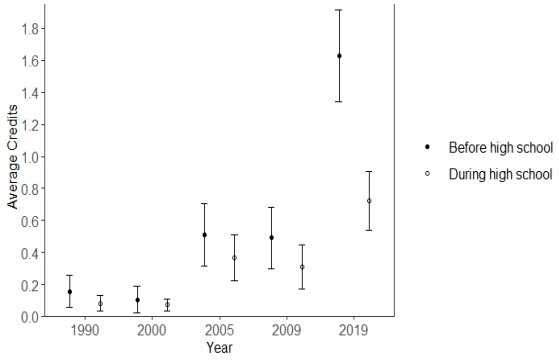


AAPI Differences across Tracks and Years

For AAPI students, there was no significant difference in mean Carnegie credits for the different Algebra tracks in 1990, 2000, 2005, or 2009. The only statistically significant difference was in 2019, with early Algebra earning more average credits. The lack of statistically significant differences for each year preceding 2019 may reflect previous research findings that Asian students have a higher chance of progressing to advanced mathematics in high school even without early Algebra (Edosomwan et al., 2022). When looking at differences from year to year, while there were no statistically significant differences from 1990 to 2000 for either track, there was a jump from 2000 to 2005, with students on both tracks earning more credits than their peers. From 2005 to 2009, the data show a decrease in both tracks, although the decrease was not statistically significant. From 2009 to 2019, there was a statistically significant increase in the number of credits earned for both tracks, but the gap between the two tracks also increased.

Figure 3

AAPI Students Average Advanced Credits by Algebra Track

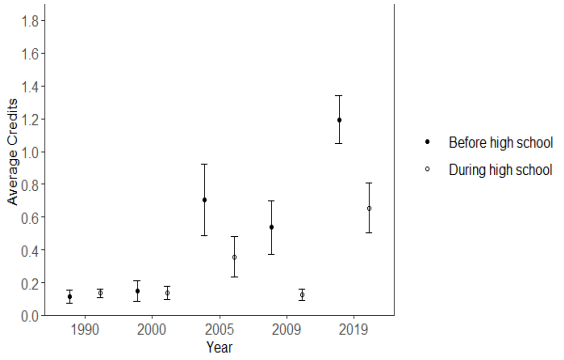


White Student Differences across Tracks and Years

There were no statistically significant differences in credits earned by the Algebra track students in 1990 and 2000 for White students. As with Black and Latinx students, the differences did not become significant until 2005 and continued into 2009 and 2019, where early Algebra students were statistically significantly more likely to earn advanced credits. While in 2005 the CIs were similar in magnitude and precision, in 2009 and 2019, there were substantial gaps between CIs between early and non-early Algebra tracks. As with Black and AAPI students, there was a decrease in the earning of advanced credits for both tracks from 2005 to 2009 that was not statistically significant before a statistically significant jump for both tracks from 2009 to 2019. White non-early Algebra students in 2019 earned similar amounts of advanced credits as early Algebra students in 2005 and 2009. So, although each track increased the amount of advanced credits earned, the gaps between the tracks also increased. However, visually speaking, the gap between intervals from 2009 to 2019 has not increased as much compared to other racial/ethnic groups.

Figure 4

White Students Average Advanced Credits by Algebra Track



Limitations

This study looks only at aggregate data by racial group across years. The lack of individualized data limited the types of analysis that could be performed. It also limited our ability to consider multiple control values related to who takes Algebra I early, such as student socioeconomic status (SES) and parent levels of education. Therefore, the data can only give generalized observations about comparisons across racial groups and time that must be considered in light of the lack of controls for other factors besides race found significant in the literature.

Another issue is the lack of gender and racial subgroups in the model, which would be needed for a more intersectional data analysis. By considering Asian Americans and Pacific Islanders together, we could not see the differences between those groups. This aggregation is potentially problematic because the U.S. Department of Education (2018) has noted those groups' different participation rates in early Algebra, with Asian Americans having almost double the participation of Pacific Islanders. Future research should add gender and SES and disaggregate Asian American Pacific Islanders information in the data.

Discussion

In light of these findings, we must discuss the patterns in advanced credit attainment for racial groups across time before explicitly looking at how those patterns change in light of early Algebra I credit. From 1990 to 2019, all racial/ethnic groups earned more advanced credit regardless of when they took Algebra. The one exception in increased credits observed was in the change from 2005 to 2009, possibly because of the 2008 financial crisis, although that is beyond our data. The trend has generally been growth in the number of advanced credits. That growth pattern is consistent with the increased number of students from all backgrounds taking Advanced Placement courses and exams (Klugman, 2013).

The gap between those on early and non-early Algebra tracks has increased, with early Algebra students earning more advanced credits starting from 2005 for every group except for AAPI, where the gap did not become significant until 2019. Our results show that, as of 2019, taking Algebra before high school corresponds with the magnitude of advanced credit earned and adds to the research on the benefits of taking Algebra in middle school. This result supports previous data about educational attainment increases with early Algebra course taking (Edosomwan et al., 2022; Lee & Mao, 2021; Rickles, 2013). It also supports patterns that indicate that despite increased enrollment in advanced courses for Black and Latinx students, racial gaps in advanced course-taking continue (Klugman, 2013; Rodriguez & McGuire, 2018).

Marginalized students continue to face disparities in equity in access to advanced mathematics coursework. Our results add to this body of research by looking at general advanced course credits for 12th graders, which differs from previous studies examining mathematics coursework and achievement. We found that while the number of advanced course credits increased from 1990 to 2019 for all students, the gaps between those who took Algebra I early and those who did not also increased. Considering the body of research that indicates that Black and Latinx students are less likely to take early Algebra I, those gaps are disproportionately increasing for those these students, which is an issue that researchers and practitioners must address for educational equity.

As competition to enter colleges intensifies, students' advanced course-taking expectations also increase for most selective colleges, specifically in calculus, which is mostly only reached through the early Algebra I pipeline (Bressoud, 2021). This trend is reflected in the increased number of advanced courses taken by all students in the data just as more and more students take advanced classes, in contrast to when it was limited to just the elite (Klugman,

2013; Rothschild, 1999). Research has suggested that gaps in high school courses completed partially explain gaps in Black and Latinx college readiness STEM course enrollment in advanced mathematics coursework (Long et al., 2009; Rodriguez, 2023). Our research may provide supporting information for those previous findings in the literature.

Future research should take into account factors other than race. Adding gender and SES in the model could account for intersectional effects not available with the current dataset. Other factors, such as home language, should also be analyzed. A more detailed breakdown of the advanced credits students earn based on content also needs to be detailed. How do demographic factors such as race, gender, SES, and language affect credits earned after taking early Algebra I? What subject areas are students taking advanced credit in after taking early Algebra I? Could early Algebra I be a proxy for advanced pathways in multiple subject areas? The answers to these questions have value in better understanding the college readiness of diverse students.

Conclusion

In conclusion, our study sheds light on the patterns of advanced credit attainment for various racial groups over the past three decades and their correlation with the timing of Algebra I coursework, despite the previously researched benefits of early Algebra on advanced mathematics course-taking (Battey, 2013; Beattie, 2017; Moller & Stearns, 2012). Black and Latinx remain under-represented in early Algebra. The overall trend indicates a steady increase in advanced credits earned by students across all racial/ethnic groups from 1990 to 2019. However, the nuanced examination of early and non-early Algebra tracks reveals a growing gap in advanced credit attainment, particularly for marginalized students. The established positive correlation between early Algebra enrollment and advanced course credit calls for more work to increase the access, enrollment, and success of Black and Latinx students in early Algebra.

Our findings underscore the positive impact of taking Algebra before high school and earning advanced credits, aligning with existing research on the benefits of early Algebraic exposure. Despite the overall increase in advanced course credits, the widening gap poses a significant challenge to educational equity, especially for Black and Latinx students who are less likely to have early access to Algebra. As we navigate an educational landscape where competition for college admissions intensifies, addressing the disparities in access to advanced mathematics coursework is imperative. Our research echoes previous studies suggesting that gaps in college readiness, particularly in STEM courses, can be linked to high school advanced mathematics coursework inequities (Chatterji et al., 2021; Rodriguez, 2018). Researchers and practitioners must confront this issue head-on and develop strategies that ensure equal opportunities for all students.

Looking ahead, future research should expand its focus beyond race to incorporate intersectional factors such as gender and socioeconomic status. A more detailed analysis of advanced credits based on content and subject areas, considering demographic factors, will provide valuable insights into the diverse pathways students pursue after early Algebra. These considerations will contribute to a more comprehensive understanding of college readiness and inform strategies to promote educational equity. Therefore, the imperative for future research lies in exploring the multifaceted aspects of advanced credit attainment, considering factors like gender, socioeconomic status, and subject areas to foster a more inclusive and equitable educational system.

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