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Evaluating the Impact of Peer Supplemental Instruction on STEM Course Outcomes: A Five-Semester Study at an HBCU

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ABSTRACT

This study examined the impact of Supplemental Instruction (SI) on student performance in introductory STEM courses at a Historically Black College or University (HBCU). Using a non-experimental, ex post facto design, academic outcomes from 105 courses and 2,829 student grades were analyzed over five semesters. While overall course performance scores did not significantly differ between SI and non-SI groups, SI-supported courses showed significantly higher frequencies of "B" and "C" grades and a greater proportion of passing rates. These findings suggest that SI may improve academic outcomes for students at risk of failure. Institutions seeking to reduce attrition in gateway STEM courses—especially among underrepresented students—should consider SI as a scalable, equity-driven academic support model.

Keywords: academic performance, HBCUs, STEM retention, Supplemental Instruction, underrepresented students

INTRODUCTION

Efforts to improve the retention and graduation rates of underrepresented students at Historically Black Colleges and Universities (HBCUs) have been the subject of ongoing academic and institutional focus. These institutions have strategically addressed both academic and nonacademic challenges, such as financial barriers and inadequate academic preparation, which disproportionately affect underrepresented minority (URM) students. Nonacademic interventions include scholarships and financial aid initiatives, while academic strategies encompass pre-matriculation summer bridge programs and tutoring services. These measures have helped students transition into rigorous first-year curricula, particularly in gatekeeper STEM courses such as introductory biology, chemistry, and mathematics. These courses, often viewed as "weed out" classes, are critical to students' persistence in STEM majors but frequently present substantial barriers to academic progression. Traditional, faculty-centered pedagogical approaches further exacerbate challenges by failing to foster engagement or support critical thinking development, contributing to lower self-efficacy and higher dropout rates (Tobias, 1990).

Despite these challenges, HBCUs continue to play a central role in the academic success of African American students in STEM fields. Eight of the top ten baccalaureate-origin institutions of Black doctorate recipients from 2010 to 2020 were HBCUs (National Center for Science and Engineering Statistics, 2022). These institutions have demonstrated consistent success in producing African American graduates who pursue advanced degrees in science and engineering (Snyder & Dillow, 2011; National Center for Education Statistics, 2019). This success is attributed to culturally responsive educational practices, robust advising and mentoring, and targeted academic interventions that promote self-efficacy and academic persistence. The integration of such support structures is consistent with Tinto’s Model of Student Retention (1993), which highlights the importance of academic and social integration in promoting student persistence. Moreover, the collaborative, peer-led nature of academic interventions like Supplemental Instruction (SI) aligns with Vygotsky’s Social Development Theory (1978), which emphasizes the role of social interaction in cognitive development. Bandura’s Self-Efficacy Theory (1997) further supports the use of SI as a means of boosting students' confidence in their academic capabilities, ultimately improving their performance and retention.

Recent studies underscore the growing relevance of SI in addressing academic disparities among URM students. Palid et al. (2023) found that structured peer-learning interventions such as SI significantly mitigated systemic barriers for URM and female students in STEM, contributing to improved academic outcomes. Kaldaras and Wieman (2025) proposed a self-guided model that enhances math-science sensemaking among marginalized students, suggesting the importance of student-centered support frameworks. Anfuso et al. (2022) demonstrated that Peer Supplemental Instruction led to measurable gains in academic performance, especially among Black/African American students. These studies highlight the value of implementing evidence-based academic support models in fostering equity in STEM education.

Problem Statement and Hypotheses

While the benefits of SI are well-documented, few studies have investigated its impact on URM populations within HBCU contexts. Existing research tends to focus on outcomes at predominantly white institutions (PWIs), where URM students constitute a minority. The present study addresses this gap by examining the effectiveness of SI on the academic performance of African American students enrolled in introductory STEM courses at a large HBCU. Therefore, two major research questions emerge from the dearth of empirical information regarding the target population.

The first research question focuses on comparative differences between STEM courses incorporating the SI model into instructional methods versus similar STEM courses that do not use the SI model. Specifically, the query is expressed as: Research Question 1– Is there a significant difference in grade-point scores of STEM courses that use the SI model compared with STEM courses that do not use the SI model? The attendant research hypothesis is stated as: Hypothesis 1– The grade-point score means for SI-model STEM courses are significantly higher than grade-point score means for non-SI model STEM courses.

$$[\boldsymbol{H1_0}\text{:}\ X_{SI} = X_{non-SI}\ ;\ \boldsymbol{H1_A}\text{:}\ \bar{X}_{SI} \neq X_{non-SI}\ ]$$

The second research question addresses the issue of pass/fail grade rates relative to use of the SI model in STEM courses. In this instance the query is stated as: Research Question 2– Is there a significant difference between the performance benchmark of 50% passing grades in STEM courses using the SI-model contrasted with STEM courses that do not the SI model? The attendant hypothesis is stated as: Hypothesis 2– The passing grade rate of 50% occurs with a significantly higher frequency for SI-model STEM courses than non-SI model STEM courses.

$$[\boldsymbol{H2_0}\text{:}\ X^2_{SI:non-SI} = 0;\ \boldsymbol{H2_A}\text{:}\ \bar{X}^2_{SI:non-SI} \neq 0\ ]$$

LITERATURE REVIEW

The Role of HBCUs in STEM Student Success

HBCUs serve as critical access points for underrepresented students pursuing degrees in STEM. These institutions employ holistic educational practices that include racially affirming curricula, community-based learning environments, and multi-layered advisement structures. Academic practices at HBCUs frequently integrate African American history and culture, promote faculty-student mentoring, and encourage participation in professional development activities. These strategies promote racial and professional identity formation, which are essential for academic persistence (Arroyo & Gasman, 2014; Baker et al., 2021; Fleming, 1985).

Further, undergraduate research opportunities supported by extramural funding play a vital role in the academic development of URM students at HBCUs. Programs emphasizing hands-on research experience and mentorship enhance students' preparation for graduate study and STEM careers (Morton, 2021; Umerah et al., 2021). These co-curricular activities often employ apprenticeship models that provide personalized guidance, aligning well with Vygotsky's emphasis on guided learning within the Zone of Proximal Development. Despite these robust support structures, first-year retention in STEM majors remains an area in need of targeted intervention. Enhancing academic performance in gateway STEM courses is essential for maintaining momentum toward degree completion.

Morgan State University: Institutional Commitment to Retention

Morgan State University (MSU) is one of several universities located along the Eastern Seaboard that historically served the African American population. The student body is largely composed of individuals from ethnically diverse backgrounds, with 76.3% identifying as African American, 5.8% as Hispanic, and 3.2% as multiracial. A substantial portion of the student body, more than 95%, receive financial aid for meeting tuition obligations and 55% of enrollees are Pell Grant eligible. During the past decade MSU's enrollment has surged in growth to over 10,000 undergraduate and graduate students. The institution holds a Carnegie R2 classification based on high research activity and the awarding of doctoral degrees in STEM disciplines, ranging from engineering and computer science to urban infrastructure systems and psychometrics.

Morgan State University (MSU) exemplifies the HBCU commitment to improving student outcomes. Through initiatives such as the "50 by 25" campaign, MSU has implemented best practices that include a summer bridge program, mandatory academic advising, and targeted tutoring services. These efforts have contributed to consistent first-to-second-year retention rates above 70%. MSU's success has garnered national recognition from organizations such as the Association of Public and Land-grant Universities (APLU) and the Lumina Foundation.

Evidence supports the effectiveness of these strategies. First-year transition programs have been shown to positively influence student persistence (Pascarella et al., 1986). Intrusive advising and structured academic support services also improve retention and performance (Habley, 2004; Annis, 1983). However, despite MSU's progress, additional efforts are needed to support STEM students, particularly in gateway courses where failure rates remain high. SI presents a promising strategy for enhancing performance in these courses.

Effectiveness of Supplemental Instruction

Originally developed to reduce attrition in professional programs, SI has evolved into a widely adopted model for peer-assisted learning (Blanc et al., 1983; Martin & Arendale, 1992). Research demonstrates that SI improves course grades, reduces DFW rates, and increases student engagement (Dawson et al., 2014; Moog et al., 2008). Students who attend SI sessions consistently perform better than those who do not, with gains observed across disciplines and institutions (Arendale, 1997; Martin et al., 1997; Allen et al., 2021; Bowman et al., 2021).

However, few studies have directly examined SI outcomes for URM students at HBCUs. Bowman et al. (2021) reported higher retention gains and lower DFW rates among URM students at a PWI, yet the sample size was small and lacked generalizability. Anfuso et al. (2022) observed that SI particularly benefited underprepared students at a Hispanic-serving institution but did not isolate outcomes by race. Recent work by Anfuso et al. (2025) now confirms SI's efficacy for Black students specifically. These findings, coupled with the gap in research at HBCUs, underscore the need to evaluate SI's impact in a more racially homogeneous academic setting.

The present study seeks to contribute to this evolving discourse by assessing the effect of SI participation on course grades and retention outcomes for African American students at Morgan State University. By integrating established learning theories and addressing the lack of HBCU-specific data, this study provides a critical evaluation of SI as a tool for promoting equity and academic excellence in STEM education.

RESEARCH METHOD

This study employed a non-experimental, ex post facto (causal-comparative) research design to evaluate the effectiveness of the Supplemental Instruction (SI) model in improving student performance in undergraduate STEM courses at a Historically Black College or University (HBCU). While randomized experimental designs offer stronger causal inference, such methods are rarely feasible in real-world educational settings, where variables such as course enrollment, faculty teaching styles, and access to academic interventions cannot be fully controlled. Instead, this study utilized naturally occurring course groupings to compare academic outcomes between students enrolled in SI-supported courses and those in non-SI courses (Creswell, 2009; Gay, Mills, & Airasian, 2009; Franklin & Osborne, 1971; Selltiz, Wrightsman, & Cook, 1976).

Sample and Course Clusters

A purposive sampling strategy was used to select courses and student records, consistent with the constraints of an ex post facto design. The unit of analysis was the undergraduate STEM course, with student final grades serving as the primary performance outcome. Data were collected across five consecutive academic semesters—Spring 2020 through Spring 2022—and included 105 introductory-level STEM courses with a total of 2,829 student grades**.** Courses were categorized into three primary discipline-based clusters:

- **Introductory Biology**: 41 courses; 1,025 student grades
- **Chemistry**: 28 courses; 693 student grades
- **Mathematical Analysis**: 36 courses; 1,111 student grades

The SI model was introduced during the Spring 2020 semester. Due to variability in faculty adoption and limited staffing resources, two naturally occurring instructional groups emerged:

- **SI-supported courses** (n = 65): 1,715 student grades
- **Non-SI courses** (n = 40): 1,114 student grades

A cluster sampling approach was used to group student performance data at both the course and cluster levels for comparative analysis (Ferguson & Takane, 1989; Kish, 1995; Winer, Brown, & Michels, 1991).

Measurement and Scoring

The primary performance metric was the final letter grade earned by students in each STEM course. These grades were converted to ordinal numeric values to facilitate quantitative analysis:

- A = 5
- B = 4
- C = 3
- D = 2
- F and Withdrawals = 1

This ordinal transformation supports index construction—a commonly accepted method in educational and behavioral research for quantifying latent variables such as academic performance (Tukey, 1977; Nunnally, 1967; Babbie, 1973; Winborne, 1991). Two performance indices were constructed for analysis:

1. **Scholastic Performance Index (SPI)**: An aggregated course-level metric based on the converted numeric values of all student grades in

a given course. SPI scores ranged from 30 to 92, with higher values indicating stronger overall course performance.

2. **Letter Grade Frequency Index**: A proportionalized score was generated for each letter grade category (A through F) to quantify the frequency of each grade type within a course. These scores ranged from 0 to 77, with higher scores reflecting greater success in that grade category.

Together, these indices allowed for meaningful comparisons between SI and non-SI course groups, providing insight into the effectiveness of the SI model in improving academic performance in introductory STEM courses.

RESULTS

As indicated in the problem statement, this research was undertaken to examine the effectiveness of the SI model on academic performance levels of students enrolled in STEM courses. Over five consecutive semesters at an HBCU, the SI model was used to support instruction within introductory level courses in biology, chemistry, and mathematics. Letter grades earned by STEM course enrollees, largely freshmen, served as the unit of analysis. However, a cluster sampling method was used to produce a data configuration that would align with the problem statement and attendant hypotheses.

Research Question 1 centered on differences that might occur in earned letter grade pattens for SI model STEM courses when compared with non-SI model STEM courses. Given the study's *ex post facto* design, two continuous measures were generated from letter grades earned by undergraduates within the sampled STEM courses. Consider first, the SPI scores. This continuous measure summarized academic performance for each individual course in the cluster sample. The SPI scores possessed all the numeric qualities of continuous measures in statistics, thereby allowing for significance testing to be applied.

Table 1 presents findings from an independent *t*-test analysis conducted on SPI scores as the dependent variable. The independent or group variable was type of instruction used in the course. Specifically, the SI model courses (n = 65) were contrasted with non–SI model course (n = 40). As shown in Table 1 the t- ratio of t = 0.54 (df = 103) did not reach the critical region of statistical significance. The mean for the SI model courses was Mn = 61.11 (sd = 12.80) and the non-SI model courses had a mean of Mn = 61.57 (sd = 16.59). These means were nearly identical in value, a result that did not support the research hypothesis of significant differences between the two differing approaches to STEM instruction.

"Grade index" scores were the second continuous measure generated from letter grades earned by undergraduate students enrolled in STEM courses. Highlighting, again, that the unit of analysis was a grade attained by each course enrollee is an important rationale for use of Hotelling's *T*-squared. Focusing on the cluster sampling design, there were 2,829 total student grades embedded within the $N = 105$ STEM courses forming the research sample clusters. Based on the *Central Limits Theorem* of sample size, it is expected that a large array of numerically transformed letter grades would gravitate centrally (Kerlinger, 1986; McNemar,1969). That trend was prominent in the previous t-test analysis, where the contrasted mean were nearly identical. In this second examination of Research Question 1, the focus changes to an exploration of each grade type, "A" to "F," for the relative influence of the SI model classes contrasted with the non-SI model classes.

Table 1
Summary of t-test on "Scholastic Performance Index" scores for SI Model (n = 65) versus non-SI Model (n = 40) STEM courses[1]

Type of Instructional Model	*Mn*	*sd*	range
SI Model	61.11	12.80	30 - 92
non-SI Model	61.57	16.59	31 - 88

t-ratio = 0.54, *df* = 103

[1]Note: the possible score range is 1 to 100 points.

$*p < .05$; $**p < .01$

Table 2
Summary of Hotelling's Multiple t-Test on the five grade-index scores by "SI Model" versus "non-SI Model" types of STEM courses" (N = 105)

Grade Score	Type of Course		
	SI Model	non-SI Model	*F*-ratio

	Mn	*sd*	*Mn*	*sd*	
"A" grade	20.37	17.31	25.34	19.86	2.09
"B" grade	26.30	14.36	19.72	19.86	4.84*
"C" grade	23.41	13.84	18.05	11.67	4.17*
"D" grade	8.39	8.17	9.82	9.85	0.64
"F" grade	17.38	13.22	22.48	15.23	3.28
Hotelling's T-squared $F = 2.23$					

*P < .05; df = (1, 103)

Table 2 presents the results of a Hotelling's Multiple *t*-Test analysis on the five grade-index scores by SI model STEM courses compared with non-SI model STEM courses. The overall contrast of mean scores did not prove statistically significant, as reflected in the broader analysis of variance outcome. Specifically, the summary statistic of $F = 2.23$ ($df = 1, 103$) did not reach the critical region. Consistent with previous findings from the *t*-test, this overall *F*-ratio result was consistent with central trending of SPI scores. However, there were significant differences found in the score comparisons for "B" and "C" grade index scores. The Hotelling's approach allows for the examination of multiple paired comparisons of means within a single sample without violating confidence levels. Essentially, the T squared analysis protects against committing a Type I error regarding rejecting the null hypothesis (Mertler & Vannatta, 2017; Jackson, 2023; Maxwell, 1977). For the "B" grade-index scores, an *F*-ratio of $F = 4.84$ proved statistically significant at the 95% confidence level. The respective mean scores were $Mn = 26.30$ ($sd = 14.36$) for SI model courses and $Mn = 19.72$ ($sd = 19.86$) for non-SI model courses. It is important to note that each individual course could attain a possible grade index score of 0 to 100, based on the scoring algorithm. Comparison for the three other grade index scores of "A," "D," and "F" did not produce statistically significant outcomes.

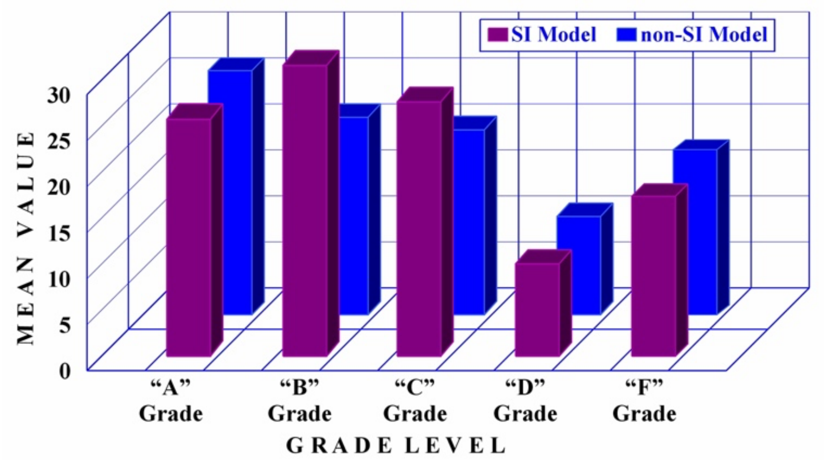

Figure 1. *Distribution of mean letter-grade means for"SI Model" (n=65) versus "non-SI model" (n=40) STEM course types.*

Figure 1 provide a visual representation of the comparison of grade index scores for SI model STEM courses compared with non-SI model STEM courses. Noting that bars within the graph reflect the means for each grade, the statistical findings from the T-squared are visually revealed. The most striking differences in bar heights were shown for the "B" and "C" grade means. More grades clustered at these two levels for the SI model courses than the grades for the non-SI model courses. Although there were no statistical differences for the "D" and "F" grade comparisons, the graphic representation reveals that more grades clustered toward the low end of the graph for non-SI model STEM courses than for the SI model STEM courses.

The second research question augmenting this study addresses SI model influences in a more binary manner than the prior question. More specifically, Research Question 2 engaged passing rates for STEM courses where the SI model was implemented weighed against those STEM courses not using the model in service of undergraduate students. A criterion of 50% was established for testing the attendant statistical hypothesis for this research question. Letter grades of "A," "B," and "C" are the standard indicators for successful completion of course requirements in higher education and were used in this analysis. A binary indicator variable was created for all STEM courses in the cluster sample. Values of one were assigned to STEM courses where 50% or more of the enrolled undergraduates earned a "C" or higher grade. Those STEM courses that had fewer than 50% of enrolled students attaining a "C" or higher grade were assigned values of two. This binary indicator of passing constituted one independent variable in a contingency table analysis. The second independent variable was the status of SI model usage or non- SI model usage for each STEM course.

Table 3

Chi-square test results for performance benchmark of 50% student passing rate in STEM courses defined as "SI Model" (n = 65) or "non-SI Model" (n = 40) type

Course Type	50% or Above Pass Rate		Below 50% Pass Rate	
	f	%	f	%
SI Model	59	90.8%	6	9.2%
non-SI Model	30	75.0%	10	25.0%

Chi-square = 4.77*; Contingency Coefficient = .21*
*p<.05, **p<.01

Table 3 shows results of a contingency table analysis on cluster sample data, using the aforementioned criterion of a 50% student passing rate. The chi-square statistic value of X^2 = 4.77 ($p < .05$) proved statistically significant at the 95% confidence level. Delving into the contingency values, the analysis revealed that 90.8% of the STEM courses using the SI model to augment instruction achieved the criterion passing rate. In contrast, the STEM courses of non-SI model status had a passing rate of 75.0%. This finding resulted in acceptance of the research hypothesis attendant to Research Question 2. Further, the outcome bolstered the meaningfulness of results from the T^2 analysis, where greater values for "B" and "C" grade scores emerged through contrasts between SI model and non-SI model STEM classes. This contingency table analysis particularly strengthens research findings herein because of its nonparametric nature. The robustness of this outcome is not challenged by a lack of randomness in sampling or an implicit need for variable manipulation. The chi-square analysis amply supports outcomes from the previous parametric tests.

DISCUSSION AND CONCLUSIONS

This study examined the impact of Supplemental Instruction (SI) on student performance in introductory STEM courses at a Historically Black College and University (HBCU). While mean grade comparisons did not reveal statistically significant differences between SI-supported and non-SI courses (Table 1), a deeper investigation into grade distributions (Table 2) and categorical shifts using chi-squared analysis (Table 3) provided critical insights. These results affirm that SI's value may not lie solely in raising average grades but in redistributing student outcomes—particularly among those at risk of failing.

Specifically, SI appeared to support students at the margin of passing, shifting grades toward higher performance tiers (Figure 1). High-achieving students likely succeeded regardless of intervention, but those struggling were better able to achieve satisfactory outcomes when SI was available. These findings support the hypothesis that SI is particularly effective for URM students in challenging STEM courses at HBCUs, reinforcing its potential to reduce academic failure.

Importantly, this study intentionally excluded variables such as high school GPA, demographic differences, or prior academic achievement. The goal was to assess the SI model in its "purest" form within a homogeneous student population. The uniform implementation of SI and the deliberate avoidance of session attendance tracking allowed for a more unbiased evaluation. This approach, while limiting in some respects, provides a focused assessment of how SI functions in an environment where student academic backgrounds and institutional context are relatively stable.

While this study supports the effectiveness of SI in shifting grade outcomes and supporting at-risk students, the benefits may be even greater if institutions can increase attendance among those most in need. However, research suggests that students at risk for academic failure are often the least likely to seek help, in part due to stigma associated with remedial support (Walton & Cohen, 2007; Cox, 2016). This stigma—especially prevalent among URM students—can undermine self-efficacy and exacerbate feelings of academic alienation.

To address this issue, SI must be reframed as a mainstream academic tool rather than a remedial intervention. Institutional strategies such as proactive outreach, endorsement by faculty, and structured participation incentives can help normalize SI engagement. Promoting a growth mindset by positioning SI as a proactive skill-building opportunity may encourage broader participation, particularly among students who may internalize academic struggles as personal deficiencies.

Additionally, future research should examine how students' goal orientations—specifically mastery vs. performance goals—interact with SI engagement and outcomes. Mastery-driven students may derive deeper benefits from SI as they are intrinsically motivated to understand material, while performance-driven students may prioritize immediate academic success. Understanding these differences could inform how SI sessions are framed and facilitated.

Another promising avenue for exploration is the role of personality traits such as self-monitoring and commitment orientation in shaping SI effectiveness. Students who are naturally inclined to monitor and adapt their academic behaviors may benefit more from SI, raising the possibility that differentiated SI models—tailored to personality and learning disposition—could further enhance outcomes.

IMPLICATIONS

The findings of this study have significant implications for how institutions implement and promote SI programs, particularly at HBCUs. First, they suggest that SI is an effective equity-oriented intervention that can support URM students in STEM by improving performance among those who may otherwise be at risk of failing. Given the consistent challenges faced by underrepresented students in foundational STEM courses, SI offers a replicable and scalable strategy for improving retention and academic success.

Second, the results underscore the importance of addressing help-seeking stigma, particularly among students from marginalized backgrounds. Institutional messaging, faculty involvement, and structural supports must reinforce SI as a high-impact learning strategy, not a last resort. Framing SI as an opportunity for collaboration and academic enhancement can shift cultural perceptions, increasing engagement and reducing barriers to participation.

Third, the study highlights a need for future interventions to consider student motivation and disposition in the design of academic support. Tailoring SI strategies to align with mastery goals or to accommodate different personality traits may maximize the benefits for diverse learners. This would mark a shift from a one-size-fits-all model to a more personalized and effective approach.

Finally, these insights contribute to the broader conversation about inclusive pedagogical models in higher education. SI aligns with established theories of student development, including Tinto's emphasis on academic and social integration, Vygotsky's focus on collaborative learning, and Bandura's model of self-efficacy. Implementing SI within HBCUs and other minority-serving institutions can therefore serve as a key strategy in advancing educational equity and supporting the academic trajectories of underrepresented students in STEM fields.

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