Mathematics Placement, Courses, and Use of Local Data in the STEM Mathematics Pathway in Predominately Black Institutions

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Racial disparities, whether in terms of student outcomes or faculty representation, are a persistent feature of the field of mathematics education (Battey & Leyva, 2016; Martin, 2009). To counter this trend, *Transitioning Learners to Calculus I in Community Colleges* (TLC3; Burn, Mesa, Wood, & Zamani-Gallaher, 2016) brings together an interdisciplinary research team to help mathematics programs identify and remove barriers for students of color in the STEM (science, technology, engineering, and mathematics) mathematics pathway. In the context of community colleges, the STEM mathematics pathway includes initial mathematics placement and mathematics courses that can range from developmental mathematics to calculus I and II. The purpose of this article is to present and highlight institutional practices implemented at African American enrolling community colleges. We focus on three areas of practice explored in the TLC3 national survey of community college mathematics chairs: mathematics placement, STEM mathematics courses, and the use of local data (Burn, Mesa, Wood, & Zamani-Gallaher, 2018). To center the analysis on students of color, we disaggregate the TLC3 national survey data by quintiles based on the percentage of African American student enrollment (Table 1). To explicate how mathematics placement, STEM mathematics courses, and use of local data interacted in practice, we supplement the analysis with case study data collected from a Predominately Black Institution (PBI), Haynes College (a pseudonym),[1] that enrolls 54% African American students. This article is most useful to faculty and administrators working to close racial equity gaps in the STEM mathematics pathway by allowing them to situate their efforts and institutions amongst national data and the case study.

Literature

Approximately 2.5 million African American students enroll in postsecondary institutions in the United States, 30% in public two-year colleges (U.S. Department of Education, 2017). Studies have long shown that African Americans, along with women, Hispanics/Latinx, Native Americans, and Southeast Asian Americans, are underrepresented in STEM education (Brainard & Carlin, 1998; Museus, Palmer, Davis, & Maramba, 2011; Starobin & Laanan, 2008). Non-Hispanic whites earned 65% of bachelor degrees (1.2 million) in 2015–16, 18% of which were in STEM fields. In contrast, African Americans earned 11% of bachelor degrees (194,500) (de Brey et al., 2019, p. 146), 12% of which were in STEM (p. 156). This has adversely affected the workforce: Indeed, Black employees make up only 6% of employees in STEM fields, whereas White employees account for 72% of the STEM labor force (Malcom, 2010).

Multiple factors influence student success in the STEM mathematics pathway, including mathematics placement, curriculum,

[1] The pseudonym Haynes College was selected to honor Martha Euphemia Lofton Haynes (1890–1980), the first African American woman to earn a PhD in mathematics in 1943 (Williams, 2001).

instruction, student support, and use of local data (Bressoud, Mesa, & Rasmussen, 2015; Burn, Mesa, & White, 2015; Wood, Harris III, & White, 2015). These factors mutually reinforce one another and involve institutional stakeholders inside and outside of the mathematics program (Bryk, Gomez, & Grunow, 2010). This article focuses on mathematics placement, STEM mathematics pathway courses, and the use of local data, because these factors can have a disproportionate impact on students of color. More specifically, STEM-interested students who begin in developmental mathematics are less likely to remain a STEM major compared to students who did not take developmental mathematics (Hodara, 2019). Because students of color are disproportionately represented in developmental mathematics, ensuring accurate placement of students into their initial mathematics course and offering developmental mathematics courses that effectively transition students to precalculus is essential to supporting STEM majors of color (Cullinane & Treisman, 2010; Melguizo, Kosiewicz, Prather, & Bos, 2014; Seymour & Hewitt, 1997). Further, examining outcomes data disaggregated by race/ethnicity and gender is an essential first step to identifying inequitable student outcomes that may otherwise remain hidden (Harris III & Bensimon, 2007).

Methods

The TLC3 national survey (Burn et al., 2018) was cast during 2017 to mathematics chairs or their designees at the nation's 1,023 associate degree-granting institutions.[2] We received responses from 455 unique campus sites (44% response rate) that were representative of the nation's community colleges in terms of location, size, and setting.[3] For each college in the sample, we merged in data from the Integrated Postsecondary Education Dataset (IPEDS) (Institute of Education Sciences, 2018), including graduation rates and student demographics. For the present analysis, we used the SPSS software package to create quintiles based on the percentage of African American enrollment for the colleges in the sample (Table 1).

We ran descriptive statistics and cross tabulations for variables of interest around placement, STEM mathematics pathway courses, and use of local data. The present analysis shares aggregate findings and highlights practical differences of 10 percentage points or more between colleges in the 5th quintile of percentage African American enrollment (20% or more African American students) and colleges in the 1st and 2nd quintiles (less than 6% African American students). When practical differences emerged between these two groups and cell counts were greater than 10, we ran Chi-square tests of independence. We report the level of significance regardless of whether it met the standard .05 threshold. In doing so, we honor current concerns around practical versus statistical significance and "bright-line" thinking around *p*-values (Rosling, Rosling, & Rosling Rönnlund, 2018; Wasserstein & Lazar, 2016). We avoid post hoc tests with multiple pairwise comparisons, given the descriptive nature of this study and our inability to control for other factors that may be contributing to observed differences. For example, we are sensitive to the effect of institutional size and state-level policies on institutional practices.

Regarding our case study, Haynes College is a public, two-year college located in the suburbs of a major Midwest city with close proximity to several state colleges and universities. Haynes College is in the 5th quintile based on percentage African American enrollment, with 54% African American students. We selected the college for case study based on their responses to the TLC3 national survey, which revealed program features known to disproportionately positively impact students of color in the STEM mathematics pathway. In addition, a preselection interview with the mathematics program chair confirmed their commitment to improving outcomes for African American students at their college. The college serves approximately 3,900 students, with 14 full-time and 12 part-time mathematics faculty. Three members of the TLC3 research team conducted a two-day site visit in 2018. Data collected included six mathematics classroom observations ranging from developmental mathematics to calculus II, five interviews with mathematics faculty, of which two were either current or past mathematics department chairs at the college, and two focus groups totaling eleven student participants. Each interview was analyzed through an iterative process of reading and reflective memo writing (Emerson, Fretz, & Shaw, 1995) to create a description of mathematics placement, STEM mathematics courses, and use of local data at Haynes College.

Findings

To begin, we present Table 1 showing selected institutional characteristics of colleges in the TLC3 sample, disaggregated by percent African American enrollment quintiles. It is noteworthy that the TLC3 sample mirrored the national data on the quintile cut-points. For example, in both the TLC3 and national data, colleges in the 1st quintile enrolled 2% or fewer African American students while colleges in the 5th quintile enrolled 20% or more African American students.

Table 1 shows that graduation rates are similar across the quintiles (16% to 26%) but are generally lower for African American students (8% to 13%). Across all quintiles, retention rates are lower for part-time (40 to 45%) compared to full-time students (57 to 61%). By examining the median and maximum FTE and the number of full-time and part-time faculty, we can

[2] The TLC3 National survey was cast to public two- and four-year colleges that primarily award associate degrees.

[3] For complete details of the final TLC3 sample, the TLC3 national survey technical report can be found at https://occrl.illinois.edu/tlc3.

Table 1

Institutional Characteristics of TLC3 Sample by Percentage African American Enrollment Quintiles[a]

	Quintiles by Percentage African American Student Enrollment				
	1st (n = 94)	2nd (n = 88)	3rd (n = 90)	4th (n = 87)	5th (n = 93)
African American enrollment	0 to 2%	2.1 to 5.9%	6 to 9.9%	10 to 19.9%	≥ 20%
Graduation rate (African American)[b]	25% (8%)	26% (13%)	22% (10%)	20% (9%)	16% (10%)
Median FTE[c] (max FTE)	1257 (8534)	1859 (11743)	2270 (14722)	3273 (25614)	1848 (18074)
Full-time (part-time) retention[d]	58% (40%)	60% (43%)	61% (46%)	61% (45%)	57% (40%)
Number full-time (part-time) mathematics faculty[e]	5.5 (8)	9.7 (12)	9 (17)	11 (25)	8 (12)
Number states represented	35	28	32	25	25

Notes. [a] Percentages presented represent the median. Data comes from the U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), Fall Enrollment component final data (2007–2016) and provisional data (2017), with the exception of number of full- and part-time faculty, which comes from self-reported data from TLC3 national survey respondents.
[b] Based on first-time, full-time degree seeking undergraduate students completing their program within 150 percent of normal time.
[c] Full-Time Equivalent student enrollment.
[d] Fall-to-fall retention rates for full-time, first-time, degree/certificate seeking undergraduates.
[e] There were colleges in each quintile of the sample where the maximum number of part-time faculty exceeded 100.

infer that colleges in the 1st quintile tend to be smaller than the other quintiles. We also note that while each quintile includes colleges from multiple states, eight states are disproportionately represented in the 5th quintile: Alabama, Georgia, Louisiana, Maryland, Mississippi, New Jersey, North Carolina, and South Carolina.

Placement

National Survey Findings

Respondents to the national survey selected the top three characteristics from a list of ten[4] that they believe contribute to the success of STEM-interested students in the STEM mathematics pathway at their campus. Accurate placement of students into their initial mathematics course was selected in the top three by 59% of the survey respondents, with roughly one out of four (23%) ranking it first. Accuplacer was the most common form of placement measure used across all colleges in the sample (68%) followed by SAT/ACT scores (58%). Twenty-three percent of colleges reported using high school grades for placement. Colleges in the 5th quintile of African American enrollment more often reported using placement exams developed by the state (23%) than colleges in the 1st and 2nd quintiles (5%).[5] The latter were more likely to use ALEKS (13%) and high school mathematics grades (30%) compared to 5th-quintile colleges, where 2% reported using ALEKS and 16% reported using high school mathematics grades.

Table 2 shows whether colleges reported making changes to their mathematics placement policies in the past two years along with several placement policies that may help students avoid taking unnecessary mathematics courses, disaggregated by percent African American enrollment quintiles.

Table 2 shows 40% of colleges in the 5th quintile reported no changes to placement in the past two years, which was higher than any of the other quintiles. Additionally, colleges in the 5th quintile less often reported having test-out policies for all courses in the STEM mathematics pathway (37%) or policies to allow students to place higher by approval of the instructor (26%) compared to the other quintiles. While not shown in Table 2, it is noteworthy that the use of test-out policies decreased as the mathematics level went higher: 75% of the TLC3 sample reported having test-out policies in developmental math compared to 65% in precalculus and 56% in calculus I and II.

Table 2

Selected Placement Policies by Percent African American Enrollment Quintiles[a]

	No changes to placement in the past two years[b]	Policy to test out at all STEM mathematics levels	Policy for higher placement by educator at all STEM mathematics levels
5th Quintile	40%	37%	26%
4th Quintile	26%	54%	39%
3rd Quintile	36%	49%	40%
2nd Quintile	31%	57%	44%
1st Quintile	23%	50%	44%

Notes. [a] 1st Quintile (0 to 2%), 2nd Quintile (2.1 to 5.9%), 3rd Quintile (6 to 9.9%), 4th Quintile (10–19.9%), 5th Quintile (20% or more African American students enrolled).
[b] The TLC3 national survey was conducted in 2017.

Placement at Haynes College

Accurate placement was a priority for Haynes College. At the time of the study, the college utilized ACT/SAT scores or the ALEKS placement test (a recent switch from Compass) to determine student placement in mathematics courses. However, beginning fall 2019, the college implemented the use of high school mathematics grades for Algebra I and Algebra II in addition to ACT/SAT scores. ACT/SAT scores and high school mathematics grades are used for placement into college algebra or below, whereas ALEKS scores can be used to place students as high as precalculus or calculus I.

[4] The 10 priorities (% selected as a top priority) were high-quality instruction (81%), high-quality academic support (60%), accurate placement into initial mathematics course (59%), active learning (34%), uniform course components (22%), faculty professional development (13%), student advising around transfer (12%), instructor meetings around course delivery (7%), effective use of local data (7%), and student social support programs (7%). (See Burn et al., (2018) for complete details.)

[5] Low cell counts prohibited inferential tests. We note that 32% of colleges in the 4th quintile reported using placement tests developed by the state.

Notable placement policies at Haynes College include requiring students who take the ALEKS test to complete a mandatory review of no less than three hours prior to attempting the placement test. One student detailed her experience,

> With the math, you cannot take the math test that day. You have to take a pretest and complete it [the review] before you can take the placement test in math only. They do give us materials, study guides and the [ALEKS] website to go to. And we have to put in the hours before we are eligible to take the math placement.

Students can attempt the ALEKS test five times, with a limit of twice per semester, allowing students the ability to remediate between attempts. The mathematics department chair shared "the system [ALEKS] has a built-in remediation tool where it analyzes their correct answers, their wrong answers." A faculty member added, "The software makes them a pie chart of where they're strong and where they're weak and provides what's needed to shore up skills." Students may also retake the placement test if they believe their score placed them into a class above their perceived level of content mastery. Data regarding the effectiveness of ALEKS was not yet analyzed due to its implementation 18 to 24 months prior to the study. The Research Testing Coordinator at Haynes College explained during an interview that "85% of our students were placing into developmental but the numbers are going down since ALEKS and the implementation of remediation."

Haynes College allows faculty members teaching the three lowest levels of developmental mathematics to advance students to the next course by "testing out" or obtaining a course grade that demonstrates mastery of content. A student recalled her experience in testing into a higher course,

> When I first took the placement test, they put me in a [developmental] class. But when we get to the class it was like okay, we're going to give you this test to see if you really belong here. When I took the test, I ended up being removed from that class and being placed into college level.

STEM Mathematics Courses

National Survey Findings

At the developmental level, the top five course options reported by the chairs were: traditional lecture (79%), online (58%), compressed courses (47%), differentiated pathways for STEM and non-STEM (47%), and modularized or emporium models (37%).[6] A statistically significant higher percentage of colleges in the 5th quintile reported offering the modularized or emporium model (52%) compared to colleges in the 1st or 2nd quintiles (32%, $p < .01$) The national survey revealed less variation in course options at the precalculus or calculus I and II levels compared to developmental mathematics. The majority of the respondents reported that the STEM mathematics pathway at their college included college algebra (70%), trigonometry (63%), precalculus, elementary functions or analytic geometry (46%), and one third or fewer offered combined courses such as precalculus and trigonometry (33%) or college algebra and trigonometry (18%). Introduction to mathematical modeling was offered by 2% of colleges in the sample.

Overall, 92% of the respondents reported offering stand-alone calculus I and II, and the number of colleges that offered some other calculus option (e.g., calculus for first-timers, compressed calculus, calculus for engineering or life sciences) was in the single digits and typically less than 2%. One exception was honors calculus, which was offered by 12% of the respondents. Colleges in the 5th quintile were more likely to report that the primary instructional format[7] was lecture plus computer-based instruction in both precalculus (24%) and calculus (22%) than colleges in the 1st and 2nd quintiles (10% in precalculus and 9% in calculus, $p < .01$).

STEM Mathematics Courses at Haynes College

Mathematics curriculum at Haynes College is strictly aligned with statewide articulation initiatives. Mathematics faculty are provided with course outlines at the start of each academic year, which provide guidelines as to what topics are to be covered and how many class periods or how much time should be spent on specific topics. Most of the mathematics courses at Haynes College, both lower- and upper-level courses, are offered in traditional face-to-face lecture, web-enhanced, online, and hybrid/blended formats. In a few cases, courses are paired with a "structured learning component," where students learn complementary skills to enhance their mathematics experience. During the semester of the site visit, two developmental mathematics courses were offered that included a structured learning component.

Interviews reflect that most adjustments are made at the developmental and lower-division mathematics course level, with very little variation to the upper-level courses. Recently, the mathematics department chair implemented changes for the

[6] Survey respondents were asked whether they offered the following modalities at the developmental level: traditional lecture, online, compressed course, differentiated pathways for STEM and non-STEM, modularized or emporium model, self-paced, corequisite models (coenroll in developmental and college-level math), corequisite model (developmental mathematics linked with writing), or learning communities.

[7] Survey response options were: Lecture and answering student questions, Lecturing incorporating some active learning techniques, Minimal lecture with mainly active learning techniques, Lecture plus computer-based instruction, and There is too much variation across sections to identify one style.

lower-level mathematics courses, "I'm changing some of our lower-level classes [Basic Mathematics, General Mathematics, and Prealgebra] into accelerated courses where students don't stay in the developmental sequence too long." A faculty member expanded on the revamping of the developmental courses,

> We revamped that whole [developmental mathematics] program and made all three of them all two-hour courses. At one point they were all three-hour courses. So we've taken it from nine to six credit hours.

This change to the lower developmental mathematics courses was influenced by several factors, including cost and the number of students that enroll in and remain stuck in developmental mathematics coursework, as mentioned in interviews with faculty, the mathematics department chair, and the Testing Research Coordinator. Results specific to the effectiveness of these changes is not yet available as data has not yet been analyzed by the institution.

Use of Local Data

National Survey Findings

Effective use of local data to monitor the STEM mathematics pathway was selected by 7% of chairs as a top priority. Table 3 shows the survey options, reports of local data use, and whether the data was disaggregated. Overall, 45% of survey respondents reported having "readily available" access to data, 49% reported having access to data that was "not readily available," and 17% reported examining data disaggregated by race/ethnicity. A higher 56% of colleges in the 5th quintile reported having readily available access to data compared to 42% of colleges in the 1st and 2nd quintiles ($p < .10$).

In the aggregate, the majority of survey respondents reported that they most frequently examined student performance in mathematics courses (80%), student evaluations (64%), the effectiveness of developmental mathematics (64%), and student learning outcomes (56%). Colleges in the 5th quintile were more likely to examine student evaluations than colleges in the 1st and 2nd quintiles (71% vs. 58%, $p < .05$) and were less likely to examine the effectiveness of placement recommendations (39% vs. 52%, $p < .05$). In addition, 5th-quintile colleges were more likely to report examining data related to transfer compared to colleges in the 1st and 2nd quintiles (31% vs. 21%, $p < .10$). This finding is noteworthy, as 20% of respondents from the 5th-quintile colleges ranked effective student advising related to transfer as a top priority, in contrast to 9% of colleges in the 1st and 2nd quintiles ($p < .05$).

Table 3

Use of Local Data Reported by TLC3 National Survey Respondents (n = 449)

	N	%
Student performance in mathematics courses	360	80%
Effectiveness of developmental mathematics	287	64%
Student evaluations	286	64%
Student learning outcomes	251	56%
Effectiveness of placement recommendation	196	44%
Tutoring Center Data	192	43%
Transfer data	109	24%
Student exit interviews	18	4%
Data disaggregated at all	206	46%
by race/ethnicity	77	17%
by age	58	13%
by gender	76	17%
by time status (full- or part-time)	76	17%

Use of Local Data at Haynes College

There were inconsistent understandings around the use of local data at Haynes College. Responses provided to the national survey indicated that data was not readily available and not disaggregated; however, data is reviewed on student performance in mathematics classes, effectiveness of developmental mathematics courses, student evaluations, and effectiveness of placement recommendation. According to the former department chair, "they don't really provide us with much as faculty members. Any kind of data analysis we do in our department, we have to ask for that data specifically or we may not get it." She indicated, however, that data related to placement was readily available, as the department chair was an administrator on the ALEKS site. In contrast, the current mathematics department chair explained that student-level data is always accessible, "whenever we want to see their placement scores, transcripts, history, see where they're coming from, we always have access to that."

Faculty interviewed described that student-level data is limited to student demographics, placement scores, transcripts, and academic history. Other faculty spoke of access to data specific to percentages related to student success rates, literacy, and final exam scores. One faculty member commented, "sometimes we get percentages, [which] students are going to succeed, how many have succeeded, and what levels of literacy they come into the college with." Several faculty members also mentioned receiving findings from a departmental outcomes assessment demonstrating students' ability to understand and apply concepts in appropriate ways, which they can use to identify areas (topics) in which students are experiencing difficulty and to influence the order and timing of various mathematics topics.

Consistent with the responses on the mathematics chair survey, faculty members indicated data is not disaggregated. The current mathematics department chair indicated that he had no knowledge of data being disaggregated to examine outcomes for African American students. One faculty member commented,

> I think that most of the numbers we get are basically based on that population [African American] because that's our biggest population here. I don't think there needs to be much of a breakdown of those numbers because that's the largest segment we serve here.

Implications for Practice and Research

The findings of this study can help colleges situate their efforts and institutions amongst national data and the case study. Mathematics placement and developmental mathematics interact and mutually reinforce each other. Both areas of practice need attention. Undertaking these twin redesign efforts benefits all students but may have a disproportionately positive impact on helping STEM-interested students make progress and maintain momentum, given the length of the STEM mathematics pathway. Further, these twin efforts can bolster the success of students of color who disproportionately place into developmental mathematics. Haynes College is a positive example of a college working to remove barriers by shortening the developmental mathematics sequence and increasing the accuracy of initial mathematics placement. Yet the mathematics program at Haynes College reported little use of disaggregated student data that might help them understand the impact of these changes on African American students at their college.

The national survey data revealed several differences in practices across the quintiles based on the percentage of African American student enrollment. Colleges in the 5th quintile were less likely to have made changes to mathematics placement within the past two years and to have policies that allow students to test out of mathematics courses or to allow higher placement by an educator. Colleges in the 5th quintile also relied more heavily on the modularized or emporium model at all course levels. Because of the limitations of the data, we cannot make assumptions as to why the differences occurred or their effect on African American students. However, it does raise concerns as institutions in the 5th quintile enrolled more African American students. The emporium model has the potential to enable students to accelerate through developmental mathematics, which could positively impact students in the STEM mathematics pathway. Yet results of the model are mixed in terms of student outcomes (Zachry Rutschow, 2019). Additional research is required to understand the impact specifically on African American students or the reasons for the differences between the quintiles.

The findings also suggest that mathematics programs are not using data as effectively as they could. We see an opportunity to examine student outcomes data, disaggregated at a minimum by race/ethnicity within gender to determine whether African American students are experiencing equitable outcomes in the areas of retention, learning, and progression through the STEM mathematics pathway. Limited institutional resources around access to data may require mathematics programs to undertake their own data collection to understand where their STEM majors are starting in the developmental mathematics curriculum and how well they are transitioning on to the precalculus and calculus level. In general, we need to increase our collective capacity to analyze and make policy based on disaggregated data.

Conclusion

Nearly a third of college students interested in STEM enroll in two-year colleges, and many need additional support to become college ready in mathematics (NPSAS, 2016). As a result, colleges across the country are simultaneously undertaking mathematics placement and curriculum redesign. At the same time, external stakeholders look to two-year colleges as an engine for increasing the racial/ethnic diversity of the STEM workforce. The survey data, as well as findings from the case study, align with prior research that indicates there are privileged classes of students in mathematics. Whiteness is normative and dominant in terms of which racial groups have been deemed to contribute to the knowledge base, are prepared, and deemed successful (Battey & Levya, 2016; Gutiérrez, 2017). As such, there is a veneer of invisibility of community colleges, particularly those serving special populations in the literature and lack of attention to naming community college mathematics as racialized spaces. Thus, colleges that enroll large proportions of students of color have increased pressure and reason to improve. Improvement involves simultaneous attention to initial mathematics placement and course offerings as a first step, and using local data disaggregated by race/ethnicity to ensure effectiveness and equity in student outcomes. We challenge institutions to look at their own practices and policies in relation to mathematics placement, curriculum, and use of data. How is student success conceptualized? What is being lost by not disaggregating by race/ethnicity? How can disaggregating data inform college policies and practices around placement, curriculum, and support to produce more equitable outcomes for all student populations? How are your institution's practices in these areas promoting and supporting the success of the various subpopulations of students?

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