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Utilizing Additional Measures of High School Academic Preparation to Support Students in their Math Self-Assessment

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ABSTRACT
This study describes student behavior through the actual assessment and placement (A&P) process. It then uses an alternative A&P policy that utilizes an additional measure that assesses prior math preparedness alongside subtest choice. Utilizing data from a community college that allows its' students to choose the assessment subtest used to place them, we find a misalignment between students' subtest choice and the highest math course they passed. After correcting for this misalignment through our alternative A&P criteria, we found that students experience increased access to higher levels of math while exhibiting similar success rates in their placed courses.

A substantial majority of community colleges require that their students be assessed in math and English to determine students' preparation for college-level work in these subjects (Parsad, Lewis, & Greene, 2003). Traditionally, developmental math education is structured as a sequence of three or four prerequisite courses leading to college-level work (Bailey, Jeong, & Cho, 2010; Melguizo, Kosiewicz, Prather, & Bos, 2014). Of entering community college students who are assessed, it is estimated that 75%, nationally, are placed into developmental education (National Center for Public Policy and Higher Education (NCPPHE) & Southern Regional Education Board (SREB), 2010; Bailey, 2009a, 2009b. In California, approximately 85% of community college students are referred to developmental math with the largest proportion referred to three levels below college-level (California Community Colleges Chancellor's Office, 2011).

Though the purpose of developmental education is to equip initially underprepared students with the academic basic skills required to successfully pass college-level courses (Bailey, 2009a, 2009b; Lazarick, 1997; Merisotis & Phipps, 2000), developmental education can also act as a barrier to students' degree completion or transfer to a 4-year college, especially among students placed into lower levels of the developmental math trajectory. Research has consistently demonstrated that students placed into lower levels of developmental math sequences exhibit substantially lower rates of enrollment and of success in passing the subsequent math courses needed to attain an associate's degree or transfer (Bahr, 2012; Bailey et al., 2010; Fong, Melguizo, & Prather, 2015; Jenkins, Jaggars, & Roksa, 2009). Moreover, this research has demonstrated that underrepresented racial minority (URM) students exhibit lower odds of successfully progressing through their developmental math sequences (Fong, Melguizo, & Prather, 2015; Bailey et al., 2010), which may result in an exacerbation of the racial disparities found in math achievement and, ultimately, degree completion.

Given the large number of students placed into developmental education, and the low success rates among those placed, research has recently emerged that takes a closer look at community colleges' assessment and placement (A&P) process. The quantitative literature has focused on

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examining the validity of standardized tests (e.g., Belfield & Crosta, 2012; Scott-Clayton, 2012; Scott-Clayton, Crosta, & Belfield, 2014); exploring additional or alternative measures (e.g., high school grades) to determine placement (e.g., Belfield & Crosta, 2012; Ngo & Kwon, 2015; Noble, Schiel, & Sawyer, 2004); and testing whether colleges are setting the cutoff scores of the placement tests correctly (Melguizo, Bos, Ngo, Mills, & Prather, 2016). An underlying theme of this literature has been the negative consequences, in terms of wasted time and resources and decreased likelihood of completing college, for students who are inaccurately placed. Research has shown that inaccurate placements affect as many as one quarter of community college students who are misassigned via placement tests (Scott-Clayton et al., 2014). Despite these negative effects, however, qualitative research has shown the complex nature of establishing the A&P criteria, and the lack of training and support available for community college faculty members charged with this task (Melguizo et al., 2014).

Qualitative research has also examined students' experiences through the A&P process, and found that they lack awareness of the process and the consequences of their performance on assessment tests (Bunch, Endris, Panayotova, Romero, & Llosa, 2011; Fay, Bickerstaff, & Hodara, 2013; Safran & Visher, 2010; Venezia, Bracco, & Nodine, 2010). Further, students' low expectations of their academic ability may be fostered in high school leading up to the A&P process (Venezia et al., 2010). And such expectations may affect the decisions they make throughout high school. Moreover, research has shown that first-generation college students, who constitute a large proportion of community college students and are often from URM backgrounds, attempt to sidestep the humiliation of failure and blow to their self-concept by undermining their educational goals (Cox, 2009). Taken together, the substantial proportion of students assessed and placed into developmental education, the negative consequences of inaccurate placement, the overall confusing and arbitrary nature of the A&P process, and the tendency for students—especially from URM backgrounds—to behave in ways that underestimate their preparation, it is imperative to conduct research that furthers understanding of the information necessary to accurately place students into levels of the math trajectory.

This study takes advantage of a California community college (College H) whose A&P policy utilizes the Mathematics Diagnostic Testing Project (MDTP) with four "readiness" subtests that vary in content-level, and enable students to choose their initial subtest. Thus, College H's A&P process includes three steps: (a) students choose which assessment subtest to take, (b) students' scores on the assessment subtest are combined with any points they are awarded via other measures, and (c) students are placed into a level of math based on their adjusted score. Unlike other traditional assessment tests (i.e., ACCUPLACER, COMPASS), the MDTP test does not include a branching system, so there is no automatic referral to a higher or lower subtest depending on how strong or weak the students are performing on their initial subtest. Meaning, while tests with a branching system are able to adjust to students' ability after they have started the test, the MDTP test does not. Because lower subtests lead to placements at lower levels, College H's policy of allowing students to choose which subtest to take has real implications for the level and accuracy of developmental education placement. College H's A&P policy, thus, allows for the identification of students who may be underestimating their math preparation.

The main contributions of this paper are to determine whether students are underestimating their math preparation, to describe an A&P policy (buffering criteria) that attempts to control for this potentially detrimental behavior, and to determine whether that A&P policy compared to College H's current process (actual criteria) differs in terms of student access and student success. Specifically, the A&P criteria we propose in this study attempts to buffer against students' lower misperceptions of their math preparation. This is exhibited by students demonstrating a higher-level of math proficiency than the content-level of the assessment subtest they choose to take.

The following research questions direct our study:

(1) Are students choosing assessment subtests that align with their prior math achievement? Does this vary by race/ethnicity?
(2) How does the inclusion of prior math achievement as an additional measure of assessment change placement distribution? Does this vary by race/ethnicity?
(3) Does student success in developmental math differ between students placed under the buffering criteria compared to students placed under the actual criteria? Does this vary by developmental math level?

The structure of this paper is as follows. In the subsequent sections, we review the current research on the accuracy of assessment instruments (i.e., standardized tests, multiple measures) employed to direct placement into developmental education, as well as the literature on how community college students' confidence interacts with their decision-making and academic behavior through the A&P process. Next, we describe the institutional context and data, providing an in-depth description of College H's A&P process and our buffering A&P criteria. We then describe our empirical strategy to compare the likelihood of success for students under each A&P criteria, followed by our main findings. Our findings suggest that including students' prior math achievement (nested within subtest choice) as part of the placement criteria increases access to higher levels of math while also maintaining success rates in their placed courses. We conclude with a discussion of these findings and their direct implications for policy and practice.

Review of Relevant Literature

The Predictive Validity of Assessment Instruments and Multiple Measures Associated with Student Success in Developmental Education

Standardized Tests

The majority of colleges utilize standardized and commercially-available tests to assess students' academic preparation and place students into levels of math based on their test score (Burdman, 2012; Hughes & Scott-Clayton, 2011; Parsad et al., 2003); presently, the two most commonly used standardized assessment tests are ACCUPLACER and COMPASS (Primary Research Group, 2008). One of the advantages of utilizing standardized tests to place students is that it can be less time-consuming and less resource-intensive to administer than a more holistic approach to placement that includes student interviews or reviews of individual files and transcripts (Hughes & Scott-Clayton, 2011). While prior research has demonstrated a positive relationship between these test scores and college students' grades in their final math course and overall grade point average (GPA) (Peng, Le, & Milburn, 2011), what is most useful to practitioners is to determine whether these tests are accurately placing students into developmental- or college-level math.

Sawyer's (1996) decision-making framework defines placement accuracy as simply placing students at the highest level of math where they have the greatest likelihood of success. These rates have been calculated as "the sum of 'observed true positives'—students who are placed at the college level and actually succeed there—and 'predicted true negatives'—students who are not predicted to succeed at the college level and are 'correctly placed into remediation" (Scott-Clayton, 2012, p. 7). Research generated by test producers has demonstrated placement accuracy rates of 73% to 84% when the criterion is a grade of C or higher in college-level math for the ACCUPLACER test (Mattern & Packman, 2009). Meaning, 73% to 84% of students were placed into college-level math and passed the course. For the COMPASS test, American College Test ([ACT], 2006) reported accuracy rates of 63% to 68% when the criterion is C or higher.

While the ACCUPLACER and COMPASS tests serve as assessments that report students' test scores in order for colleges to determine students' level of math placement, the MDTP is a test that attempts to "diagnose" rather than "report" students' math preparation (Betts, Hahn, & Zau, 2011). The MDTP, a diagnostic test utilized in a number of secondary and postsecondary institutions in

California, offers course-specific assessments that provide feedback on students' strengths and weaknesses in math (further description on how it is adopted in the community college A&P process is in the Institutional Context and Data section). Betts et al. (2011) evaluated the effect of mandatory MDTP testing on San Diego Unified School District (SDUSD) students' math achievement. They found that MDTP testing boosted California Standards Test math scores. Betts et al. (2011) determined that these gains arose in part because students were more accurately placed into math classes that aligned with their ability. (California Standards Test (CST) is the main test in California used to measure student proficiency and to determine whether schools should receive interventions and sanctions set out in the federal No Child Left Behind law.)

The College Board and ACT have reported relatively high accuracy rates for their ACCUPLACER and COMPASS products, and Betts et al. (2011) have demonstrated MDTP's placement accuracy among high school students. However, independent research examining the community college student population has reported positive but weak correlations between placement test scores and student pass rates for developmental and college-level math courses (Jenkins et al., 2009; Scott-Clayton et al., 2014). Further, research has consistently demonstrated that when alternative measures of student academic preparation are accounted for, the positive relationship between test scores and success diminishes (Armstrong, 2000; Belfield & Crosta, 2012; Scott-Clayton, 2012). This has motivated interest in understanding the usefulness of employing multiple measures to make placement decisions (Burdman, 2012).

Multiple Measures

Multiple measures have been explicitly recommended in the *Standards for educational and psychological testing* to improve the quality of high-stakes decisions. Standard 13.7 stated it this way (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999):

> In educational settings, a decision or characterization that will have major impact on a student should not be made on a simple test score. Other relevant information should be taken into account if it will enhance the overall validity of the decision. (pp. 147–148)

The call for multiple measures in assessments has emerged as a result of the increasing use of high-stakes testing as a policy tool to assist in decisions like whether students should graduate, teachers should be promoted, and schools should receive funding (Chester, 2003; Henderson-Montero, Julian, & Yen, 2003), and of course, whether students are in need of remedial education (Burdman, 2012; Hughes & Scott-Clayton, 2011; Parsad et al., 2003). While there has been widespread agreement in the use of multiple measures, "the definition of multiple measures, criteria to evaluate each measure, and how these measures should be combined for use in high-stakes decisions are not clear" (Henderson-Montero et al., 2003, p. 7). Henderson-Montero et al. (2003) defined four primary approaches in which information from multiple measures can be used: conjunctive, compensatory, mixed conjunctive-compensatory, and confirmatory. The conjunctive approach is where information across multiple measures requires a minimum level of performance across all included measures. In the compensatory approach, poor performance in one measure may be off-set by strong performance in another measure. The mixed approach uses a combination of conjunctive and compensatory approaches. Lastly, the confirmatory approach is where information from one measure is utilized to confirm the information from another measure.

Given the definitions put forth by Henderson-Montero et al. (2003), the compensatory multiple measure approach is the most useful, and perhaps more so, the most likely to be used in placement decisions for developmental education. However, the underlying assumption of this approach is that the measures included "assess knowledge, skills, and abilities" relevant to success in college-level coursework (p. 9).

From a simple empirical design argument, using multiple measures for developmental math placement is beneficial in placement decisions for several reasons: (a) it has the potential of increasing placement accuracy because of the additional information utilized to make placement decisions; (b) it can allow institutions to exempt from testing students who, given prior achievement and other factors, are predicted to have a high probability of success in a college-level course; and (c) it can decrease students' anxiety due to the high-stakes nature of a placement test (Sawyer, 1996). Noble et al. (2004) found that "using multiple measures to determine students' preparation for college significantly increases placement accuracy" (p. 302). Boylan (2009) advocated for an assessment system that combines cognitive and affective data along with information regarding students' personal circumstances (e.g., weekly work hours, parental status, marital status, financial obligations) to improve placement accuracy and serve students more effectively. Similarly, Gaertner and McClarty (2015) identified six dimensions shown to influence college readiness and success: academic achievement (e.g., test scores); motivation (e.g., academic self-concept); behavior (e.g., absences); social engagement (e.g., participation in school clubs); family circumstances (e.g., socioeconomic status); and school characteristics (e.g., school demography). They found that, among middle-school students, while the academic achievement dimension explained the most variance in college readiness (17.1%), the nonacademic factors of motivation and behavior also explained a substantial proportion of college readiness (15.3% and 14.1%, respectively). In terms of reducing the racial disparity in success in higher education, Hoffman and Lowitzki (2005) argued that prior academic achievement is the key for minority student success. For example, Marwick (2004) found that Latino students at a single community college who were placed into higher-level courses due to multiple measures achieved equal and sometimes greater outcomes than when placement was solely determined by their test score.

High School GPA

High school grades have been found to better predict student achievement in college than typical admissions tests such as the ACT or Scholastic Aptitude Test (SAT) (Bowen, Chingos, & McPherson, 2009; Geiser & Santelices, 2007; Geiser & Studley, 2002). This relationship may be even more pronounced in institutions with lower selectivity and academic achievement (Sawyer, 1996). Research has commonly included high school GPA in models predicting student success in developmental education. This literature has consistently demonstrated that high school GPA is a better predictor of student success than placement test score (Armstrong, 2000; Belfield & Crosta, 2012; Burrow, 2013; Jaffe, 2014; Lewallen, 1994; Long Beach Promise Group, 2013; Scott-Clayton, 2012).

In fact, when controlling for high school GPA, the correlation between placement test score and success disappears (Belfield & Crosta, 2012; Burrow, 2013). With access to a data system that connects high school transcript information to the local community college, the Long Beach Promise Group (2013) demonstrated that students who were placed in courses via a "predictive placement" scheme based on high school grades instead of test scores were more likely to complete college-level courses in their remediated subject areas. Armstrong (2000) studied community college students in California and found that test scores and demographic (e.g., race/ethnicity); dispositional (e.g., past experiences); and situational (e.g., employment hours) variables contributed significantly to models predicting course grades and student retention. However, the student dispositional factors tended to explain a greater amount of variance in student outcomes than did other student-level variables, including test scores. Specifically, students' previous performance in school, such as high school GPA, grade in last English or math course, and number of years of English or math taken in high school were strongly predictive of college outcomes in both English and math courses. These findings may be explained by the ability of report card grades to assess motivation and perseverance (Bowen et al., 2009), or competencies associated with students' self-control, which can help students study, complete homework, and have successful classroom behaviors (Duckworth, Quinn, & Tsukayama, 2012).

Scott-Clayton (2012) evaluated the predictive validity of COMPASS test scores to make placement decisions (developmental or college-level) compared to the predictive value of other measures used in place of, or in addition to, test scores. She found that the incremental validity of placement tests relative to high school GPA as predictors of success is weak (Incremental validity seeks to answer if a new test increases the predictive ability beyond an existing test). However, adding test scores to a model utilizing high school GPA to predict grades in college-level math increased the explained variance by six percentage points. Scott-Clayton's additional simulations also found that allowing students to test out of remediation either by their placement test scores or high school GPA resulted in lowering the remediation rate by eight percentage points without significant decreases in success rates in college-level coursework.

Utilizing Multiple Measures in the A&P Process

While the extant literature has consistently demonstrated that high school GPA is predictive of student success, there is little research examining whether the use of these measures in the A&P process is an effective practice in terms of access and success for community college students. One exception is the study by Ngo and Kwon (2015) that examined how utilizing multiple measures to assess and place students is related to access and success. They found that multiple measures increased access to higher-level math courses, particularly for African American and Latino students. Specifically, they found that measures of prior math achievement and high school GPA were useful for making placement decisions. When comparing the outcomes of students whose placement was increased due to the points they received from multiple measures (referred to as a multiple measure boost) to students who placed similarly without the multiple measures boost, Ngo and Kwon found that boosted students performed no differently on course passing rates and longer-term credit completion.

Similar to Ngo and Kwon (2015), the current study examines the extent to which multiple measures are effective in the A&P process. However, the current study adds to this literature by including a multiple measure that attempts to off-set poor and uninformed choices students are making in their A&P process that may lead to lower and inaccurate placements.

Student Experiences with the A&P Process

Colleges' A&P processes are meant to sort students into levels of math and English that best match their academic abilities. However, qualitative research has highlighted student confusion around this process, which leads to inaccurate placements and decreases in student motivation. Venezia et al. (2010) found that although research has demonstrated the negative relationship between remedial placement and student success, student focus groups and interviews with counselors revealed that entering-community-college students had little-to-no knowledge of what to expect in terms of the A&P process or the consequences of performing poorly on the test. In their research brief, Fay et al. (2013) highlighted similar patterns in student perspectives on the A&P process, and reasons why students do not prepare for these high-stakes tests. Findings revealed that students are ill-prepared because they lack knowledge regarding available preparation materials, lack understanding of how to prepare for these tests, and lack confidence in their math ability. Fay et al. (2013) concluded that academic confidence can impact student motivation and academic behaviors related to success.

Research has consistently demonstrated that across populations and subject areas, students' academic performance is associated with confidence. Much of this research is from the educational psychology literature on self-efficacy. Self-efficacy is a construct developed by Albert Bandura. In his Social Cognitive Theory, self-efficacy (Bandura, 1997) is the belief people have regarding their ability to succeed in a particular situation. He theorized that the beliefs people hold regarding their capability and expected outcomes of their efforts have a powerful influence over the ways in which they behave. Given this theoretical definition, self-efficacy has been described as analogous to self-confidence (Schunk, 2011). Research has consistently demonstrated that across populations and subject areas, self-efficacy and confidence are associated with academic performance.Bickerstaff, Barragan, and Rucks-Ahidiana (2012) showed how entering college students' confidence is shaped by past academic experiences and expectations of college. Cox (2009) examined how the fear of failure shaped students' expectations and behaviors finding that first-generation college students attempt to sidestep the humiliation of failure and blow to their self-concept by undermining their educational goals. Though most of the students she interviewed entered the community college with aspirations of ultimately attaining a bachelor's degree, they revealed tremendous anxiety over assuming the role of "college student," and feared being unable to succeed in this role. Once students sensed a mismatch between their ability and their new role, they relied on "strategies for balancing their hopes and fears," and this balancing act had a "greater influence on [students'] approaches to college coursework than did their cognitive-academic preparation" (p. 54).

Confidence has been shown to play a significant role in academic success; further, students from particular minority groups who exhibit lower math achievement also display lower confidence in their math ability (Gray-Little & Hafdahl, 2000; Oakes, 1990a, 1990b). Research has demonstrated Latino students report less confidence than their White counterparts regarding their ability to successfully complete math problems (Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). Contrary to previous research that has demonstrated lower confidence in math ability among underrepresented minority groups, Pajares and Kranzler (1995) found African American students' confidence in math ability to be more complex. Compared to White students, African American students exhibited lower performance scores but higher confidence of their math ability. Pajares and Kranzler (1995) concluded that the accuracy of self-perception in math ability was substantially lower for African American students compared to White students. Taken together, findings from the literature suggest that Latino students are more likely to underestimate their math ability given their lower confidence, while African American students are more likely to inaccurately assess their math ability.

The extent to which confidence (or lack thereof) directly plays a role in developmental math placement has been demonstrated in research on student self-placement, an A&P policy where students select their own placement. While the majority of community colleges rely on a standardized, commercially-available assessment test, Kosiewicz (2013) examined one college's use of a self-placement mechanism. Kosiewicz examined the effect of being assigned to remedial math education via a test-placement method (COMPASS) compared to a self-placement method. She found that under a self-placement regime, students are more evenly distributed in the developmental math levels compared to similar students under the traditional testing procedure. However, when she explored differences for particular racial and ethnic groups, she found that the majority of African American students assigned themselves to the two lowest developmental math levels, though she asserted this result should be read with caution given the small sample sizes.

Existing research has examined the A&P process and the extent to which additional measures may improve accuracy rates of students' placements; however, it has not accounted for students' experiences prior to, and behavior during, the A&P process, which may lead to unnecessarily lower-level placements in developmental math. In this descriptive study, we take an in-depth look at students' behavior through a single community college's A&P process. As identified in Melguizo et al. (2014), in a decentralized community college governance structure like the California community college (CCC) system, the majority of governing power is localized to the community college. Therefore, colleges have autonomy in developing their own A&P policies, and as a result, these policies vary by college. We, therefore, focus on a single community college (College H) whose A&P criteria allow students to choose which assessment subtest to take.

Data and Institutional Context

Data and Sample

Our data are from the office of institutional research at the large southern California community college district to which College H belongs. We built the dataset using three different sets of collected data: the enrollment, term, and assessment files. The *enrollment file* contains student-level information related to the courses in which the student enrolled, the dates when a specific course was added or dropped, and the final grade in the course. The *term file* contains information related to the units attempted and dropped in each term along with basic student demographic characteristics such as age, sex, race and ethnicity and language. The *assessment file* contains detailed information related to the assessment process. This file includes the assessment subtest taken, test score, math placement, and information from the students' Educational Planning Questionnaire (EPQ). During the assessment process in College H, students also provide additional information regarding their past academic experiences and commitment to college via the EPQ.

Our sample includes 8,838 first-time students who were enrolled in College H and assessed between the summer 2005 and spring 2008 semesters. Overall, the students in the sample are evenly split between females (51%) and males. While the average of the sample is slightly older (21 years), which describes students who may be nontraditional, the median age is 18 years old suggesting that 50% of the students are entering the college directly from high school. The largest proportion of the students in the sample report being Latino (37%) and the second largest being White (30%). We utilize this overall sample to address the first two research questions, which examine the alignment between students' prior math achievement and assessment subtest choice, and assess changes in the placement distributions under the actual and buffering placement methods.

In order to respond to the final research question, which evaluates differences in students' success in their first math course based on placement criteria, we utilize a subset of the overall sample. For this analysis, we remove students who did not attempt a developmental math course after being assessed. Specifically, we do not include students who attempted college-level math courses because this level is comprised of a diverse set of courses at varying content levels, and it is thus beyond the scope of this paper. We also remove students who did not attempt any math course within the sequence because we are interested in student behavior and success based on two differing placement criteria; students who do not enroll in math are noncompliant with both criteria. Again, understanding these noncompliant students' behavior is outside the main purpose of this study. The median age of the sample subgroup mirrors the overall sample. However, the filter demonstrates a significant increase in the percentage of females (54%). The proportion of Latino students also increases (44%) while the proportions of Asian American (12%) and White (26%) students decrease (see Table 1).

College H's Assessment Test and Placement Criteria

The A&P process in College H includes four general steps which we will detail below: (a) students choose which assessment subtest to take, (b) students' scores on the assessment subtest are combined with any points they are awarded via multiple measures, (c) students are placed into a level of math based on their adjusted score, and (d) students decide whether or not to enroll in math. During the

Table 1. Selected student demographics for college H by data subgroup.

	Overall	Subgroup with EPQ data1
	Sample to determine placement distribution	Sample to determine Pr(success) for first math class
Female	51.11	54.08***
Age (mean)	20.60	20.41***
Age (median)	18.47	18.39
Race/Ethnicity		
Asian American	14.80	12.26***
African American	6.94	7.01
Latino	37.07	43.54***
White	29.78	26.34***
Other	11.42	10.85
Sample size	8,838	4,192

Note. 1. Does not include students with missing EPQ data and who placed into college-level math. *p < .10, **p < .05, ***p < .01

time frame of this study, College H's A&P policy was unchanged, so students with the same test scores received the same placement throughout the time period of our study.

Step 1: Choice of Assessment Subtest

The MDTP test was developed through a joint program between the University of California and California State University systems (Betts et al., 2011; Melguizo et al., 2014). Similar to other standardized and commercially-available instruments such as the College Board's ACCUPLACER and ACT's COMPASS test, the MDTP consists of a set of "readiness" subtests that vary in math content. However, unlike ACCUPLACER and COMPASS, the MDTP test does not include a computerized branching system that automatically directs students to higher or lower subtests depending on how strong or weak the students are performing on their initial subtest. Meaning, while tests with a branching system can adjust to students' ability after they have started the test, the MDTP test cannot.[4] (College H used the paper and pencil version of MDTP, however, a computerized version of MDTP was recently validated for use in 2012 by the CCC Chancellor's Office.)

Another difference between the MDTP and the more common assessment tests is that it is a diagnostic test, so each assessment test and overall test score is accompanied with a set of subscores that measure students' ability in areas within each level of math. For example, students obtain subscores on fractions and decimals within the lowest-level test, which measures principles in arithmetic and prealgebra. While the MDTP offers subscores for each assessment subtest, College H only utilizes the overall test score in the placement criteria.

College H is also an interesting case because it allows its' students to choose which assessment subtest to take rather than directing them to a specific test level. Therefore, students assess their own math preparation prior to the assessment test. All first-time students who have an educational goal of earning a certificate, associate's degree, or transfer to a baccalaureate-granting institution are required to go through the matriculation process. Matriculation at College H begins with students completing the assessment process. Upon completion of their assessment and placement, students attend an orientation that provides information about the college. All matriculating students then meet with their counselors to develop a plan to meet their educational goal. Thus, students choose their assessment subtest prior to receiving advisement.

In order of difficulty, College H offers students a choice to take the Algebra Readiness (ALR), Elementary Algebra (EA), Intermediate Algebra (IA), or Pre-Calculus (PC) sub-test to assess their math ability. In general, lower subtests lead to placements at lower levels. At College H, students are placed into one of five levels of math: arithmetic (AR), pre-algebra (PA), elementary algebra (EA), intermediate algebra (IA), or college-level math (CLM).

Step 2: Assessment Subtest + Multiple Measure Points

At most community colleges utilizing standardized assessment tests, students' test scores determine placement level via the college's preestablished cut-score criteria. In the CCCs, placement into developmental education is not legally allowed to be based on a single test score. In 1988, the Mexican American Legal Defense and Education Fund (MALDEF) filed a lawsuit that contended that the outdated assessments—used to place students in lieu of full matriculation services—resulted in tracking Latino students into required remedial coursework, which prevented their full participation in the transfer curriculum (Perry, Bahr, Rosin, & Woodward, 2010). As part of the out of court settlement in 1991, Title V regulations were revised to include the validation of prerequisite courses, assessment using *multiple measures*, and students' right to challenge a prerequisite (Perry et al., 2010).

Therefore, colleges using a standardized assessment test to place students must utilize "multiple measures," which are intended to measure other factors demonstrated to be positively related to student success. These can include such measures as motivation, high school GPA, prior math experience, and grade in last math course (Melguizo et al., 2014; Ngo & Kwon, 2015). Due to the decentralized governance of the CCC system, research examining these colleges' A&P policies has demonstrated wide variation by college in the use of these multiple measures both in terms of which measures additional points are awarded for (e.g., motivation, high school GPA); how many additional measures are included; and how many points are provided (research has demonstrated this can range from −2 to 5 points within a single district) (Melguizo et al., 2014; Ngo & Kwon, 2015).

After students complete their subtest they respond to College H's EPQ. College H then utilizes information it obtains from the EPQ. This includes information on students' past academic experiences and commitment to college; and this information is used to determine whether students would receive multiple measure points in addition to their assessment test score to place them into a math level. College H provides additional multiple measure points for high school GPA, four points are added to students' test score for an "A" average high school GPA, two additional points for a "B," and no additional points are awarded for a "C" or below. Multiple measure points can, thus, result in a student being placed into the next higher-level course (Melguizo et al., 2014; Ngo & Kwon, 2015).

Step 3: Assessment Subtest + Multiple Measure Points = Placement

Under College H's placement criteria, students may obtain an adjusted score (assessment subtest score plus multiple measure points) that refers them to take a lower-level assessment subtest; but, students are not able to obtain a score on a subtest that refers them to take a higher-level subtest. For instance, taking the lowest level subtest (ALR) will automatically result in placement into AR, PA, or EA. However, choosing to take the IA subtest will result in placement in CLM, IA, or a downward referral to the EA subtest. See Figure 1 illustrating the placement criteria. We find that though this college employs a referral system, only 2.6% (n = 234) of students are referred to a different test and are reassessed. Therefore, students' subtest choice is the initial factor in determining placement.

Step 4: Students' Decision to Enroll in a Math Course

After receiving their assessed placement level, students make a decision on whether to: (a) enroll in their placed math course, (b) enroll in a lower-level course, (c) challenge their placement level and get permission to enroll in a higher-level course, or (d) not enroll in a math course.

Restricting the sample to students who attempted any math course after their assessment, we find that, on average, only 7% of students attempt a course that is located at a different level than their math placement (93% compliance rate). As illustrated in Table 2, when we disaggregate this compliance by placement level, students placed into AR have the lowest compliance rate (60%); however, this is by design because College H specifically permits students who place into AR the

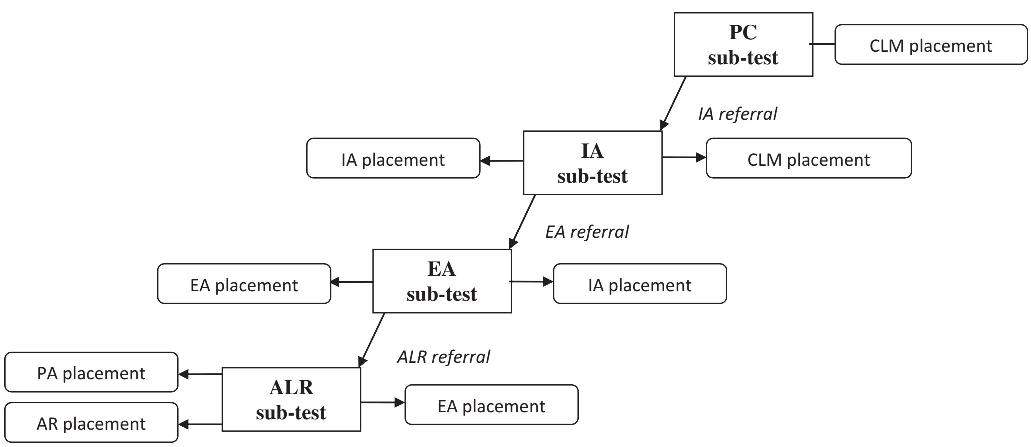

Figure 1. Math placement criteria based on assessment subtest and score.

Table 2. Compliance by level if student attempted math.

	Complier	Attempted Lower Level	Attempted Higher Level	*N*
Arithmetic	59.80	0.00	40.20	102
Prealgebra	94.14	3.04	2.82	887
Elementary Algebra	93.30	4.98	1.72	2,552
Intermediate Algebra	92.70	4.41	2.89	2,315
College-level Math	96.45	3.55	0.00	1,098
Overall	**93.21**	**4.24**	**2.55**	**6,954**

option of enrolling in PA. More surprising, however, is that a larger proportion of noncomplying students enroll in a course that is lower than their placed level than higher than their placed level.

We only look at the noncomplying group in Table 3 and see that two thirds (63%) of these students attempt a course that is located at a lower level than their placement. We also disaggregated the noncomplying group by race/ethnic group and found that a larger proportion of Latino students attempt a course that is lower than their placement (72%) while the proportion is more evenly split for Asian American and African American students.

This is important because when addressing the third research question, we restrict the sample to these noncompliant students who attempted a course located at a higher level than their actual placement.

Buffering Placement Criteria

As discussed above, College H assesses students' incoming math ability by their MDTP subtest score and high school GPA. Students' adjusted score is then used for their placement based on the college's cut-off scores. Compared to these actual placement criteria, the buffering placement criteria we use include students' prior math achievement. Under our buffering placement criteria, students earn multiple measure points for high school GPA as they do under the actual placement criteria, but we also award an additional four points if their prior math achievement was higher than their chosen assessment subtest. For example, if students passed IA in high school but chose to take the EA subtest, they are given four multiple measure points. Students receive two additional points if their highest level of math passed is equal to their level of assessment subtest. No additional multiple measure points are awarded if students take a higher-level assessment subtest compared to the highest level of math passed (see Figure 2). We chose this point scheme to be consistent with the multiple measure points awarded for high school GPA.

Choice of assessment subtest is an important first step in College H's A&P process; however, research has demonstrated that students who lack confidence in their math ability may underestimate their preparation. Taken together, when students exhibit higher proficiency but choose a comparatively lower-level assessment subtest, they may not be placed into the highest level in which they have the strongest likelihood of succeeding. Under the buffering placement criteria, we attempt to control for this underestimation by providing additional

Table 3. Noncompliers by race/ethnicity if attempted math.

	Attempted Lower Level	Attempted Higher Level	*N*
Asian	53%	47%	60
Black	52%	48%	46
Latino	72%	28%	158
White	63%	37%	141
Other	55%	45%	67
Overall	**63%**	**37%**	**472**

High School GPA	Multiple Measure Points
"A" average	4
"B" average	2
"C" or lower average	0

+

Highest Level of Math Passed	Assessment Sub-Test	Multiple Measure Points
"Calculus/Pre-Calc/Trigonometry"	PC	2
	IA/EA/ALR	4
"Intermediate Algebra/Geometry"	PC	0
	IA	2
	EA/ALR	4
"Beginning Algebra"	PC/IA	0
	EA	2
	ALR	4
"Basic Math"	PC/IA/EA	0
	ALR	2

Figure 2. Multiple measure points diagram.

multiple measure points to students who report a level of math achievement higher than their choice of assessment subtest.

Predictor Variables

Demographic Characteristics

Student demographic variables include student's reported race/ethnicity (Asian/Asian American, Black/African American, Latino, White/Caucasian, and Other/Unknown); sex; and age at the time of assessment. We utilize weighted effects coding for race/ethnicity because it allows for the comparison of each race/ethnic group (e.g., Asian American students) to the weighted average of all students in the sample. Meaning, the proportion of students in each group is representative of the average corresponding proportion of students in the college. We do not include the Other/Unknown ethnic group category in the analysis to avoid perfect multicollinearity, though this group is included to generate the weighted average. We also include covariates for students' primary home language and citizenship status to control for potential language barriers and students who were not educated in the United States' K–12 system and without the math sequence typically offered in our secondary educational system.

Responses from Educational Planning Questionnaire (EPQ)

Eight of 10 items from the questionnaire are included in our models, the two items that are excluded specifically addressed preparation in English writing. The included items consist of those that describe students' anticipated weekly time commitment to their classes and employment, the length of time spent away from education and math specifically, the importance of college to themselves and their friends and family, and past academic experience in general and specific to their experience with math (i.e., high school GPA and highest level of passed math course). While not all the items are based on a Likert-like scale—responses ranging from *Not at all important* to *Very important*—all response items are ordinal.

Level of Developmental Math Placement

The developmental math placement variable is an ordered categorical variable that identifies which level of the math sequence (AR, PA, EA, IA, CLM) students were placed into under the actual placement criteria.

Placement Criteria

A percentage of students who were assessed and placed into developmental math chose to attempt a higher course. A proportion of those students who attempt the higher course, thus, attempt the course they would have been placed into under the buffering criteria. Our placement criteria variable is a dichotomous variable where our main group is comprised of students who attempted a course higher than their placed level (buffering placement criteria), while our comparison group consists of students who attempted a course at their placed level (actual placement criteria).

Analytical Strategy

To address the first research question, we utilize descriptive statistics to explore the alignment between students' choice of assessment subtest and the highest level of math they completed with a passing grade. We describe this alignment in terms of the additional multiple measures included in our buffering placement criteria, and its' potential for reducing the racial disparities in lower-level math placements for students from URM backgrounds. We then respond to the second research question by using descriptive statistics to illustrate changes in the distribution of math placements between the actual A&P criteria and the buffering criteria.

We address the final research question by first utilizing a logistic regression model to examine whether students who attempted a higher or lower developmental math course from their placement level exhibited the same probability of successfully passing the course compared to complying students. The following empirical model was specified:

$$\Pr(y = 1|x) = \beta_0 + \beta_1 z + \beta_i x_i + e$$

Where,

y = whether students passed their first attempted developmental math course

z = buffering placement level (comparison group = actual placement level)

x = vector of student information, including demographic variables, responses to the EPQ, and level of developmental math placement

e = error term

Next, we perform a set of two-group mean-comparison t tests to compare how students who placed via the buffering criteria and those placed via the actual criteria performed in their first attempted math course. We separate these analyses by level of developmental math placement. The buffering criteria group is comprised of students who "challenged" their actual placement by enrolling in a higher-level math course. These students, therefore, attempted a course they *would have been placed* at via the buffering criteria. We exclude students who were boosted from IA to CLM because students can take several math courses at the CLM level.

As a final note, it is important to remember that this is an in-depth descriptive study focusing on College H's A&P criteria and examining what happens when an additional measure of assessment is included in the criteria. It is not our intent to make any casual inferences regarding the A&P criteria on student placement and success. We focus on changes in the math placement distribution and success in the developmental courses students are placed into and to which they are enrolled. The sample under analysis is, thus, a subgroup of the entire sample of College H's assessed student population. Because we are seeking to identify whether students have the same rates of success between actual and buffering placements, we define success as students passing their first attempted developmental math course. By doing this, we are restricting our data to students who actually attempt a developmental math course; thus, we are only analyzing students who may be more motivated than the general developmental education population (see Bahr, 2010; Fong et al., 2015). Drawing conclusions about the A&P criteria beyond the initial course is problematic because many students do not enroll in developmental education altogether, and the students who progress through their developmental sequence become a more select sample at each subsequent step (see Bahr, 2010; Fong et al., 2015).

Main Findings

(Mis)Alignment Between Student Choice of Assessment Subtest and Prior Math Achievement

The series of descriptive statistics we obtain in this study demonstrate the alignment or misalignment between students' choice of assessment subtest and what they report as the highest high school math course completed with a passing grade. There are a number of reasons students may choose subtests that are higher or lower than their level of math preparation that may derive from a misperception of ability or misunderstanding of the A&P process. For example, students may overestimate their math ability and choose a higher-level subtest, or students may underestimate their preparation and choose a lower-level subtest. Also, students may choose a higher- or lower-level subtest when they do not understand the A&P process. On one hand, students may incorrectly believe that a higher-level subtest, regardless of their score, will automatically place them into a higher math level; thus, they choose a subtest higher than their level of math preparation. On the other hand, students may incorrectly believe that if they perform really well on a subtest with lower-level content they will be placed at a higher-level.

While we do not have evidence of why these decisions are made, our study addresses how an A&P policy may protect against misinformed assessment subtest choices. Under the buffering placement criteria, students who may have underestimated their ability and choose a subtest below their math preparation are provided with additional points. Figure 3 shows a relatively equal split between students who choose a subtest that aligned with their math preparation (47%) and students who choose a lower subtest (51%).

When this figure is disaggregated by students' math preparation, we find that the greatest misalignment is between the math sequence within the K–12 system that includes geometry and trigonometry and the community colleges' algebra-focused developmental math sequence. As Figure 4 illustrates, 80 to 81% of students whose highest level of math passed was either geometry or trigonometry chose a lower-level subtest. Because of the confusing alignment between the two educational systems, it may also be argued that geometry students should be taking the EA test instead of the IA test, and trigonometry students should take the IA test instead of the PC test. If this were the case, then these students would be choosing to take the subtest at the same level as their high school course. Further, 20% and 19% of these students would be taking subtests with a higher content level than the last math course they passed. Regardless of how this multiple measure point is defined, there may be confusion around how the high school sequence translates to the community college math sequence. This especially affects 30% of the students in our sample (24% reporting geometry as their highest passed math course, and 6% who passed trigonometry).

While there is confusion for geometry and trigonometry students, there is also a tendency for a substantial proportion of students who passed beginning algebra, intermediate algebra, and

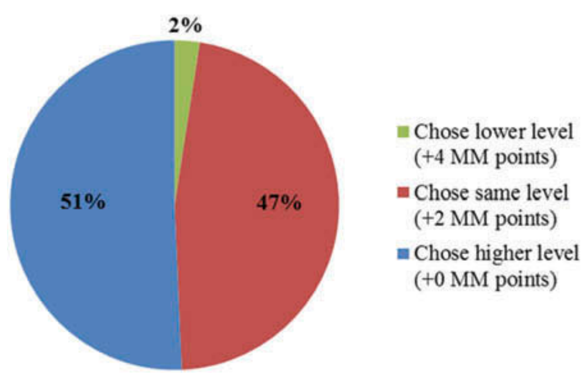

Figure 3. Student choice of assessment subtest compared to last passed math level.

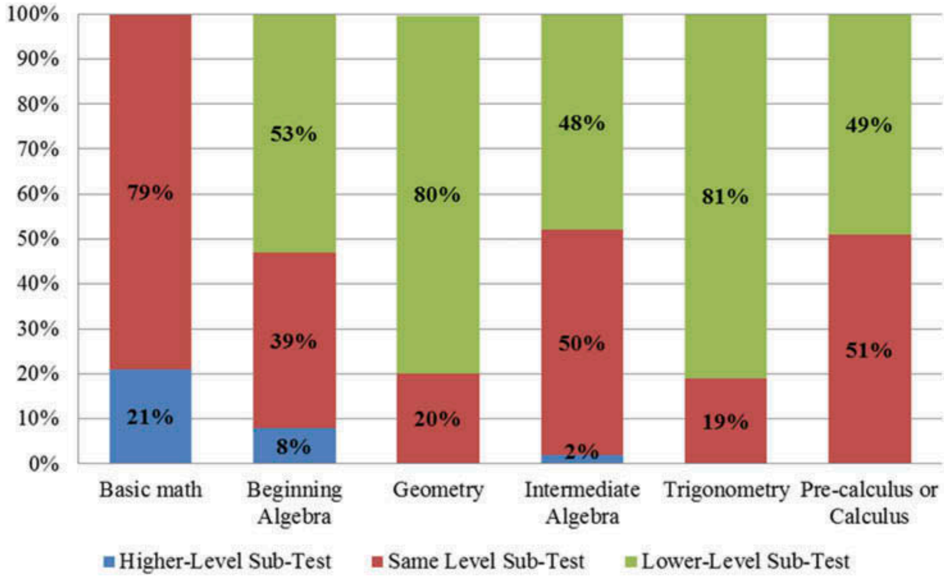

Figure 4. Alignment between student subtest choice and prior math achievement.

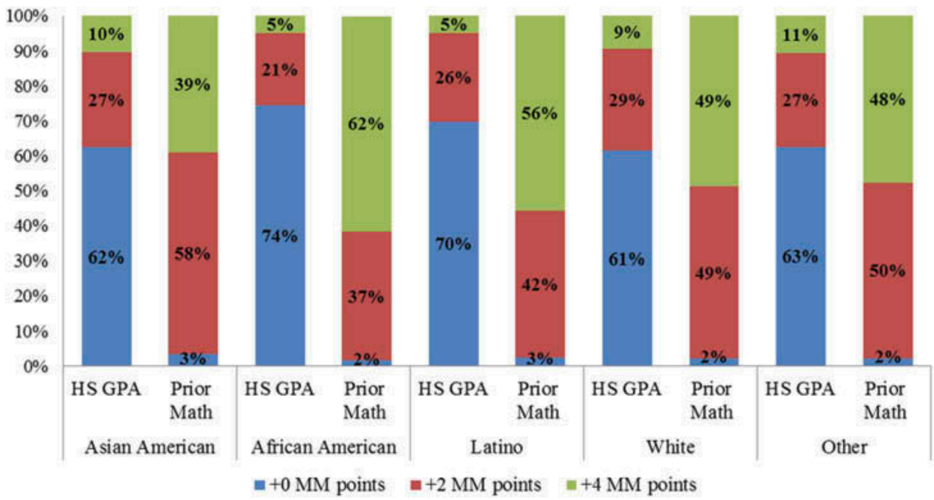

Figure 5. Distribution of multiple measure points by race/ethnicity.

precalculus or calculus to choose to take lower-level assessment subtests. About half of these students choose to take lower-level subtests; 53% of beginning algebra students take the ALR subtest instead of the EA subtest, 48% of intermediate algebra students take the EA subtest instead of the IA subtest, and 49% of precalculus or calculus students take the IA subtest instead of the PC subtest.

As previously mentioned, as a result of the MALDEF lawsuit, the use of a multiple-measure assessment and, ultimately, the creation of multiple measure points was required because using a single standardized assessment test to place students into developmental education disproportionately impacted students from URM backgrounds. We, therefore, examine how multiple measure points are distributed across racial/ethnic groups to determine whether these multiple measures actually assist in reducing the racial disparities in lower-levels of developmental math. Figure 5 demonstrates that across race/ethnicity, small percentages of students earn four multiple measure points for having an "A" average high school GPA, which is the policy under the actual College H A&P criteria (61% to 74% of students earn zero multiple measures points, and only 5% to 11% earn four points). More students earn multiple measure points under the buffering placement criteria. Approximately 39% to 62% of assessed students reported taking a lower subtest than their reported level of math course-taking, and they were, therefore, given the four multiple measure points. Of these students, the highest percentages are among URM students, which suggests that these racial/ethnic groups are more likely to underestimate their math preparation and make choices that potentially hinder success. Another interpretation may be that other racial groups are more attuned to their math level—58% of Asian American students and 49% of White students choose the subtest that aligns with the highest level of math completed with a passing grade. Taken together, our findings are consistent with prior research that demonstrates students from URM backgrounds are more likely to underestimate or inaccurately assess their math preparation (Kosiewicz, 2013; Pajares & Kranzler, 1995).

Distribution of Placements: Actual versus Buffering Criteria

Figure 6 illustrates the proportion of students placing into the five levels of math in College H under the actual placement criteria and the buffering placement criteria. This figure demonstrates that including the highest level of math completed as an additional measure of ability results in a redistribution of placements into higher levels of math. We see that while the proportion of placements into EA remain stable, placements into AR and PA significantly decrease ($p < .01$) and placements into IA and CLM experience significant increases ($p < .01$).

Looking only at students who were placed into a higher developmental math level under the buffering placement criteria, we find that the additional multiple measure points disproportionately assists students placed at the lower levels of the math sequence. Specifically, 54% of students placing into AR under the actual criteria would be placed into PA under the buffering criteria, 24% of PA-placed students would move to EA, and only 8% of EA students and 3% of IA students would have a higher placement into IA and CLM, respectively.

Figure 7 describes math placement by race/ethnicity under each placement criteria. We find that while the buffering placement criteria shift the distribution of students across developmental math levels, the racial disparities within developmental math levels do not change. More specifically, Asian American and White students continue to be placed into higher levels compared to African American and Latino students. Overall, this figure suggests that the inclusion of students' prior

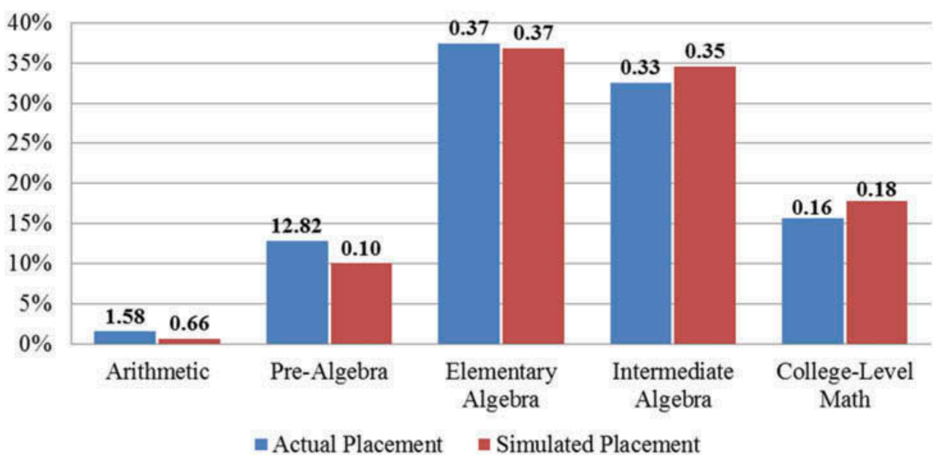

Figure 6. Distribution of actual placements and buffering placements.

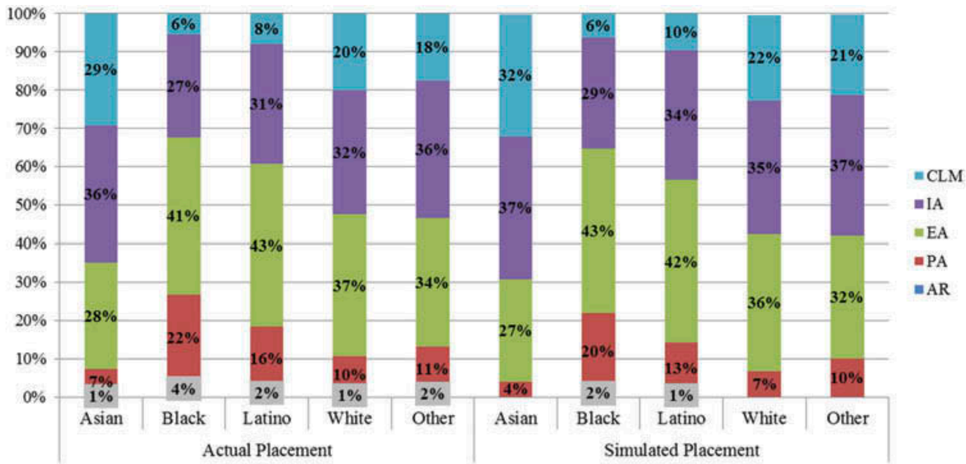

Figure 7. Distribution by race/ethnicity under actual and buffering placement criteria.

math achievement does not help in reducing the racial disparities in math placement at the highest levels of the trajectory. However, in examining the placement distribution under the buffering criteria *within* each racial/ethnic group, our chi-square analysis finds that including additional measures results in higher placements for students from each racial/ethnic group ($p < .01$). Therefore, while the buffering placement criteria do not decrease the gap among racial groups in higher- and lower-level placements, they do increase placements within each racial group.

Student Success Rates: Actual versus Buffering Criteria

Results from our logistic model, which examines the likelihood students pass their first developmental math course, are consistent with previous research. We find that female students are more likely to succeed in their first math course compared to males. For each year older a student is at the time of their assessment test, the more likely the student is to pass the first math course. The more hours students anticipate working per week, the less likely they are to succeed. Compared to the weighted-average student, Asian American students are more likely to succeed while African American and Latino students are less likely to pass their first attempted developmental math course. We also find that both prior achievement items that were utilized as multiple measures of students' assessment are statistically significant across models. Students' high school GPA and highest level of math passed are positively associated with the likelihood of passing their first developmental math course at College H.

In terms of developmental math level, we find that students placed into IA exhibit lower odds of passing IA compared to students placing into lower levels of math and passing their placed-courses (e.g. EA, PA, and AR). This finding is inconsistent with previous research that shows higher success rates at higher levels of the math sequence (Fong et al., 2015). Our finding suggests that compared to IA, lower levels of developmental math are easier courses to pass. This may be due to either students in IA being over-placed or students at lower levels being under-placed. Further, there may be variation in instructor grading practices by level of developmental math. Research has demonstrated a relatively high degree of variation in grading practices by instructors; this instability of measurements of success (i.e., final grade) thus makes accurate developmental placement more problematic (Armstrong, 2000).

Our main independent variable identifies student success based on placement under the actual compared to buffering criteria. We find that after controlling for placement level and all other

Table 4. Odds ratio of success in first attempted developmental math class.

Variables	OR	SE
Student Demographics		
Age	1.06***	(0.01)
Female	1.13*	(0.08)
Asian American	1.30***	(0.12)
African American	0.61***	(0.08)
Latino	0.83***	(0.04)
White	1.13**	(0.07)
Primary Language	1.00	(0.00)
Citizenship code	1.00	(0.02)
Student EPQ		
Hours/week plan on attending classes	1.05	(0.04)
Hours/week plan on being employed	0.90***	(0.02)
Time spent away from education	0.94	(0.06)
Importance of college (personal)	1.08	(0.09)
Important of college (family/friends)	0.93	(0.05)
H.S. GPA	1.30***	(0.07)
Highest level of math completed with passing grade	1.37***	(0.05)
Time since last math class was completed	1.04	(0.05)
Student Placement (IA = comparison)		
Elementary Algebra	1.15*	(0.10)
Pre-Algebra	1.42**	(0.19)
Arithmetic	3.28***	(1.27)
Placement Criteria (Attempted placed course under actual criteria = comparison)		
Attempted placed course under buffering criteria	0.22***	(0.06)
N R^2		3,902 0.05

*$p < .10$, **$p < .05$, ***$p < .01$

student covariates, students who attempt their buffering placement level had significantly lower odds of passing compared to students who attempt a course located at their actual placement level. Meaning, students who attempt a course at a level higher than their placement level under the actual criteria perform significantly worse than students who attempt a level of math that matches their actual placement ($p < .01$) (see Table 4).

These findings suggest that students who would have been placed at a higher-level under the buffering criteria may be over-placed and would not succeed in their initial developmental math course. However, this finding may also be a function of College H's A&P policy that permits students who place into AR the option of enrolling in PA. Following this policy, we observe that 40% of students under the actual criteria place into AR and enroll in a higher math course while less than 3% of students placing into PA, EA, or IA attempt a higher-level math course (refer to Table 2). Therefore, there is a disproportionate representation of students at each placement level under the buffering criteria. Because of this skewed distribution, as well as evidence from previous research that success varies by level (Boatman & Long, 2010; Fong et al., 2015; Melguizo et al., 2016), we next examine student success by developmental math level.

By Developmental Math Level

In the final analysis, we separate students under each placement criteria and by each developmental math level. The resulting sample sizes become too small to generate enough power to run regression models. We, therefore, utilize a series of two-group mean-comparison *t* tests to examine whether students placed via the actual or buffering criteria had similar rates of success in their first attempted developmental math course. Specifically, we compare success rates between students who attempt a higher level math course and, therefore, match their buffering placement to students who comply with their actual placement level. We found no statistically significant differences between the actual and buffering-placed students for passing IA, EA, or PA ($p > .10$). This suggests that students who do not comply with their actual placement by enrolling in the higher-level courses perform similarly to students complying with their placement. These results indicate that these buffering criteria can control for students who initially underestimated their math preparation and should be placed into higher levels of math.

Restricted to Students with Similar Scores

Because students who are placed at a higher math level under the buffering criteria are likely more similar to students who are placed into the higher math level but exhibit lower adjusted placement scores, we restrict the sample of actual criteria students to those around the cut-off score. Specifically, we examine students who are placed into a higher math level under the buffering criteria to students who are placed into the same higher math level under the actual criteria and who score five or less points above the cutoff score. Results from the sample falling within our bandwidth are consistent with the unrestricted sample. We find no statistically significant differences in success rates between students placed via the actual criteria compared to the buffering criteria ($p > .10$) (see Table 5).

When examining the overall sample, results from the logistic regression reveal that students placed by the buffering criteria perform worse than those placed by the actual criteria. However, analyzing student success rates by developmental math level, we find no significant difference in performance between students under each placement criteria. We then check the robustness of these results by restricting the sample to students around the cutoff and again find no significant differences in student success between the two criteria. Taking together results from our descriptive statistics that show a shift of student placements into higher-levels of math under the buffering criteria, along with findings from the empirical analysis indicating no significant difference in student success rates between the actual and buffering criteria, this study demonstrates how changes to A&P policies have the ability of increasing student access without decreasing student success.

Limitations

There are several limitations to this study that warrant discussion as they relate to the interpretation of our results. First and foremost, this study proposes the A&P criteria that consider students' choice of assessment subtest in relation to the highest level of math passed in order to buffer against choices that may have negative consequences in terms of students' developmental math placement. While we examine student behavior, we did not have quantitative or qualitative data that would help explain *why* or *how* students made their assessment subtest choices. Thus, we cannot be certain whether this choice is the result of lower math confidence, lack of information regarding the structure of the A&P process, or direction from peers, family, or advisors. However, we did not find any documentation of institutional policies that sorted students prior to their choosing an assessment subtest. Additionally, research has found that although the majority of colleges provide access to sample tests on their websites to assist students prepare for their assessment test, few had systematic practices in place to

Table 5. *t* tests comparing success rates between students placed by actual versus buffering criteria.

		Overall Sample				Restricted Sample†			
		n	*M*	*SD*	*t*	*n*	*M*	*SD*	*t*
IA	Actual	2146	0.70	0.44		492	0.75	0.43	
	Buffering	43	0.74	0.46	0.59	43	0.74	0.44	−0.11
EA	Actual	2381	0.66	0.47		537	0.74	0.44	
	Buffering	21	0.62	0.50	−0.42	21	0.62	0.50	−1.22
PA	Actual	835	0.70	0.46		614	0.72	0.45	
	Buffering	37	0.73	0.45	0.41	28	0.71	0.46	−0.12

$^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$
† Groups are restricted to within five points above cutoff

direct students to these online materials or other test-prep resources (Hodara, Jaggars, & Karp; 2012). Therefore, assessment subtest choice is mainly explained at the individual student-level.

Second, the results from our logistic regression that examined the probability of success report a small Pseudo-R^2, which is the statistic that describes model fit to the data. Meaning, our empirical model was not as strong a fit to the data as we would have liked. The most reasonable explanation for this is simply the lack of additional explanatory variables that relate to students' success in their first attempted math course. The literature examining the factors related to student success is expansive; unfortunately, we did not have access to many of these factors, such as achievement motivation and perseverance (e.g., Duckworth, Peterson, Matthews, & Kelly, 2007; Hagedorn, Siadat, Fogel, Nora, & Pascarella, 1999; Hoyt, 1999; Robbins et al., 2004); environmental factors like financial and familial obstacles (Crisp & Nora, 2010; Hoyt, 1999; Nakajima, Dembo, & Mossler, 2012; Schmid & Abell, 2003); or psychosocial factors like academic self-efficacy demonstrated to be related to student success (Armstrong, 2000; Krumrei-Mancuso, Newton, Kim, & Wilcox; 2013; Robbins et al., 2004). Further, we did not have access to high school transcript information (Long Beach Promise Group, 2013), so the control variables in our model, including previous academic preparation, were all self-reported measures from the students' EPQ. Lastly, developmental education research has demonstrated the relationship between student success and institutional factors such as institutional size and demography (Bailey et al., 2010; Fong et al., 2015), as well as characteristics of the actual developmental math course such as instructor grading practices (Armstrong, 2000).

A third limitation is that the sample sizes necessarily shrunk when examining differences in success rates at each developmental math level between students enrolled in courses based on the actual placement criteria and students enrolled in courses based on **the** buffering placement criteria. Because of the size limitation, we use mean-comparison *t* tests and, thus, are unable to control for other characteristics, like the factors included in the logistic regression, and that relate to success in students' initial developmental math course. As described above, we minimize some of the effect of these other characteristic differences by narrowing the bandwidth. Results from this analysis are consistent with findings from the full sample.

Discussion

A substantial proportion of students entering community colleges are assessed and placed into developmental education. Further, the majority of students entering the CCC system are placed into lower-levels of the developmental math trajectory. While these statistics are dismal, part of the large proportion of lower-level placements may be due to inaccurate A&P policies. This study takes an in-depth examination of students' behavior through their A&P process and the extent to which including prior math achievement (nested within assessment subtest choice) as an additional multiple measure may improve/increase students' likelihood of access and success.

Students Don't Know Which Subtest to Choose and are Likely to Underestimate Their Math Preparation

We first find that when students are granted agency in choosing their level of assessment subtest, it appears that: (a) there is confusion about the alignment between the high school and community college math sequence, and (b) more students choose a lower-level subtest than a subtest at the same or higher-level compared to their level of prior math achievement; this is especially the case for students from URM backgrounds. These findings are consistent with prior literature highlighting what students "don't know" regarding the A&P process (e.g., Venezia et al., 2010); and the findings may also be a result of students' lower confidence affecting their academic choices (e.g., Bickerstaff et al., 2012; Cox, 2009; Pajares and Kranzler (1995).

The misalignment between high school and college sequence may also be subject to the many math pathways for California high school students. Finkelstein, Fong, Tiffany-Morales, Shields, and Huang (2012) analyzed the math and science course-taking patterns of more than 24,000 students from 24 different California school districts and documented 2,000 course-taking patterns. In fact, they found that less than one third of the students in their sample followed paths in the top 20 most common patterns. Further, given that the existing California high school graduation requirements do not require students to take math their senior year, students may not be utilizing their senior year to prepare for college-level math. In California, there are currently only three math requirements for high school graduation: (a) pass California High School Exit Exam (CAHSEE) in math, (b) complete 2 years of math in high school, and (c) pass Algebra I (EA). Therefore, research has shown that these low high school graduation requirements mislead students into believing they are college-ready when they are not (Jaffe, 2014; Kirst & Bracco, 2004; Venezia & Kirst, 2005).

Jaffe (2014) found that the high school math path most frequently traveled by community college-bound students were less rigorous than students entering baccalaureate-granting institutions where almost 20% started in Algebra I (EA) or below and did not progress in math beyond Algebra 2 (IA). Further, nearly half of community college-bound students took no math in their senior year of high school. As they entered community colleges, Jaffe found that their CAHSEE math performance was a significant predictor of placement at all four levels below college-level math, and that not taking math in their senior year was a significant predictor for students placing two-, three-, and four-levels below college-level math. Jaffe concluded that this behavior is consistent with research documenting that students were unaware of the community college placement process and standards and, therefore, did not use their high school years to prepare (Hughes & Scott-Clayton, 2011; Kirst & Bracco, 2004; Venezia et al., 2010; Venezia & Kirst, 2005).

The Buffering Placement Criteria Increases Access Without Decreasing Success

Under the buffering placement criteria, we provide additional multiple measure points to students whose level of prior math achievement was higher than their choice of assessment subtest. By including this measure, we are utilizing information on students' prior math achievement as an assessment of math preparation, as well as attempting to control for potential confusion around the A&P subtest choice or students underestimating their math ability. We find that if College H utilized this additional measure, students would be placed at significantly higher levels within the math sequence. Further, when analyzing student success rates by developmental math level, we find no significant difference in performance between students under College H's actual placement criteria and the buffering placement criteria. We, therefore, conclude that this type of buffering criteria has the ability to increase students' access to higher levels of developmental math without decreasing success rates in those higher-level courses.

The findings suggest that utilizing high school transcript data to inform placement decisions increases access to higher levels of math for community college students. Next, in the absence of a counterfactual group that was placed according to the buffering criteria, we examine students who are noncompliant with their actual placement and essentially attempt the higher course they would have been placed in under the buffering A&P criteria. We then compare them to students who comply with their placement and find these two groups of students do not differ in success rates, even after restricting the sample to a narrow bandwidth around the cut-off. Additional information, particularly in relation to students' prior math experience that attempts to off-set lower math confidence, is a strong predictor of math success and should be given serious weight in the placement process as it increases access and maintains success. Together, these two findings suggest that a criteria that buffers against misinformed student-choice may increase student access to higher levels of math without decreasing student success. Again, these results should be interpreted with caution because the sample sizes necessarily shrunk based on our refining questions and the fact that we utilize simple mean-comparison tests.

Our findings are consistent with previous research comparing placement and success for students who were assessed and placed via a test-placement or self-placement mechanism. Kosiewicz (2013) found students who self-placed enrolled in higher-levels of math and exhibited better outcomes compared to test-placed students. Ngo and Kwon (2015) found that utilizing relevant multiple measures to place students into levels of math promote both student access and student success. Further, the Long Beach Promise Group (2013) found that students who were placed in courses via a "predictive placement" scheme based on high school grades instead of test scores were more likely to complete college-level math and English courses.

It is important to note, however, that while these additional multiple measures and the potential of student self-placement are promising for increasing access and promoting success in developmental math education, utilizing additional measures and self-placement as part of the A&P process may not reduce the racial disparities existing in math. The intent of the CCC Title V regulations, which were established in response to the MALDEF lawsuit and requires the use of multiple measures, was to combat the disproportionate impact of lower-level developmental placements for URM students. This study demonstrates that prior math achievement and lower confidence is especially prevalent for students from URM backgrounds; yet, including these measures does not necessarily have a disproportionate positive impact for these students. Thus, it is important to highlight the distance between state-wide reform efforts and policy implementation. From a policy perspective, this may mean simply that community colleges should redesign their placement formulas and provide more weight to information from high school transcripts relative to test score. It may also mean there must be more collaboration between the K–12 and community college system to incorporate early intervention programs to attempt to reduce the disadvantages students graduate from the K-12 system with and continue to have when entering the community college system.

Policy Implications

As we explored the actual and buffering placement criteria, we recognized several aspects of the A&P process that administrators should consider as they reassess their policies. First, despite the requirement to utilize multiple measures to assess and place students into developmental education, placement is still largely determined by students' assessment subtest score. Ngo and Kwon (2015) similarly reported that across the colleges within a large urban district in California, less than 5% of assessed students get "boosted" up into a higher developmental math level due to multiple measure points. Moreover, these additional points have no effect on reducing the racial disparities in developmental math placement. Thus, the manner in which multiple measure points are implemented in these colleges do not conform to the policy's intent which is to address the disproportionate impact on underrepresented minority students. Therefore, colleges should evaluate their weighting schemes, experiment with altering the number of points awarded for multiple measures, and examine whether doing this increases access without decreasing success.

Second, as we took an in-depth look at students' behavior through their A&P process, we noticed that noncomplying students are more likely to attempt a math course that is located at a level below their placement level than above their placement level. Thus, even when colleges enforce more inclusive A&P policies, students still have the ability to sabotage their own success. Early intervention programs through assessment or counseling services may assist in reducing students' tendency to create more barriers for themselves by underestimating their own math preparation.

Lastly, this study shows that a substantial proportion of students are not choosing assessment subtests that align with their level of math preparation. Much of this misalignment seems due to the differences in structure between the community college and high school math sequence. Thus, colleges should clearly provide students information comparing the courses in these two sequences to better inform students which subtest match their level of math preparation. Moreover, given that some colleges have experimented with allowing students to place themselves into levels of math they feel best matches their ability rather than being placed by a standardized assessment test (Kosiewicz, 2013), these findings suggest that students may have misperceptions of their own math preparation. Again, clearly articulating information to students in terms of their own math preparation and how it fits within the community college math sequence is crucial if students are to accurately choose the highest-level math course where they have the greatest likelihood of success.

Future Research

This study was based on an analysis of students in a single institution. However, the question of the adequacy of how students are served by an institutional assessment and placement policy is common to the majority of community colleges—not just in California but nationwide. Community colleges, nationally, serve the largest proportion of nontraditional students and students from URM backgrounds. Research has demonstrated that these students report lower math self-confidence (e.g., Jameson & Fusco, 2014; Pajares & Kranzler, 1995; Stevens et al., 2004), and thus they may need additional institutional policies to assist in overcoming behavior that may hinder success. The behavior this study measured was the misalignment between assessment subtest choice and prior math preparation. Then, through an institutional-level policy, we attempted to buffer against any misaligned choice by providing additional multiple measure points to boost a students' assessment score and, potentially, their developmental math placement. This study focused on the specific behavior of subtest choice; however, there are many intersecting points at which institutions can systematically intervene to assist students down a better-informed path.

Multiple measures may be one of the least resource-demanding interventions, and it has emerged as one of the focuses within state policies. Though California is one of the only states to have an existing multiple measure policy, several other states have introduced policies to incorporate use of multiple measures in their A&P policies for developmental math (Burdman, 2012). North Carolina, for example, has developed a customized placement assessment that includes gathering information from multiple measures such as high school grades and noncognitive measures (Burdman, 2012). The Texas Success Initiative (TSI) includes the recommendation that additional multiple measures such as high school GPA, work hours, or noncognitive measures be considered in conjunction with assessment test scores (Burdman, 2012; Texas Higher Education Coordinating Board, 2012). Connecticut's Senate Bill 40 and Florida's Senate Bill 1720 have also proposed similar policies to incorporate multiple measures.

Thus, the analyses we conducted in this study serve as useful models for other colleges and state systems interested in analyzing and experimenting with their own assessment and placement policies. This paper is intended to stimulate discussion and inquiry among community college policymakers, practitioners, and researchers seeking to improve the accuracy in the assessment and placement of students into developmental education. In what follows, we have outlined three main areas where future research can help flesh out students' experiences through the assessment and placement process to increase placement accuracy.

(1) *Measuring self-efficacy and motivational measures*. Research in educational psychology suggests that noncognitive measures—factors not specifically related to academic content knowledge or skills—are also predictive of college success and future outcomes (Duckworth et al., 2007; Heckman, Stixrud, & Urzua, 2006; Krumrei-Mancuso et al., 2013; Sedlacek, 2004). For example, self-efficacy and motivation have been found to be strongly predictive of future achievement (Duckworth et al., 2007; Krumrei-Mancuso et al., 2013; Sedlacek, 2004). While research suggests these noncognitive factors should be utilized in the A&P process (Boylan, 2009), few institutions use them in practice (Gerlaugh, Thompson, Boylan, & Davis, 2007; Hughes & Scott-Clayton, 2011). In this study, we attempted to incorporate this information through the misalignment between student subtest choice and prior math achievement. However, in order to accurately test this assumption, it should be measured. To more clearly identify the relationship between these constructs and student behavior

through the A&P process, future research should measure students' motivation and math self-efficacy.

(2) *Qualitatively documenting students' experiences through the A&P process*. Existing qualitative research examining students' experiences through the A&P process has found that students lack awareness both of the process and the consequences of their performance on assessment tests (Bunch et al., 2011; Fay et al., 2013; Safran & Visher, 2010; Venezia et al., 2010). Building upon this research, qualitative studies can flesh out students' experiences focusing on what is driving certain student choices and behaviors through their A&P process. Future research should look to examine forms of guidance students are receiving through counselors, assessment officers, faculty, and peers.

(3) *Examining the use and success of diagnostic testing*. Diagnosing where students' weaknesses are has the potential of better informing the P–16 math pathway as well as placement decisions and classroom instruction. There is some recent work suggesting that diagnostic tools may improve placement accuracy in middle- and high school mathematics (Betts et al., 2011; Huang, Snipes, & Finkelstein, 2014) and also in developmental math in community colleges (Fong et al., 2015; Rodríguez, 2014). Future research can build off this existing literature by identifying the areas of math, such as fractions or decimals, where students are experiencing the most difficulty and perhaps experimenting with placement policies that are determined by math content rather than math level. Further, research can attempt to bridge the gap between content on the assessment test and faculty instruction. For example, whether granting faculty access to their students' diagnostic results would improve student success rates.

This is an exciting time for research and practice in terms of community college developmental education programs. As more state-wide policies are enacted to improve developmental education, practitioners are continuously tasked with adopting and adapting to these policies to systematically assist students through developmental education; research is tasked with identifying what, why, and how things are or are not working. As this study has demonstrated, developmental education at the community colleges begins with the assessment and placement process. While prior studies have not been able to quantifiably examine students' choices through this process, in this study, we have attempted to observe student choice within an institution's assessment and placement criteria. It is important to recognize that while policies may be created at the state- or federal-level, they are implemented locally. Thus, they are defined through local agents and participants: community college practitioners and community college students. Research should, thus, not only continue to examine these issues as part of the larger context, but it should also pay heed to the institutional environment in which these policies are implemented and students' decisions within that context.

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