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The Role of Math Misalignment in the Community College STEM Pathway

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Abstract
Limited attention has been placed on the relationship between developmental math and STEM outcomes in community college. We therefore examine one particular experience during the transition from high school to college called math misalignment, which occurs when college students are placed lower in math than is warranted given their high-school course-taking history and record of achievement. Drawing on analysis of linked high school and community college student records, we find that a majority of students in the study sample experienced math misalignment in community college. Moreover, math misalignment especially hindered STEM-aspiring students from pursuing STEM pathways. STEM-aspiring students who experienced math misalignment were less likely to complete STEM courses than STEM-aspiring students who were directly placed in transfer-level math. This study underscores the importance of aligning academic standards across high-school and postsecondary institutions as a means of improving STEM participation.

Keywords STEM · Community college · Developmental math · Fixed effects · Inter-sector alignment

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Introduction

Increasing the number of students interested in Science, Technology, Engineering, and Mathematics (STEM) fields continues to be a focus for many educators and policymakers alike (American Association of State Colleges and Universities 2018). Several reports project that STEM-related jobs will continue to grow (National Science Board 2015; Vilorio 2014),[1] and graduates who major in STEM fields are less likely to be unemployed and are more likely to earn higher wages than graduates with a non-STEM degree (National Science Board 2015). Despite the growing demand for a STEM-capable workforce, reports and studies show that many students, especially those from underrepresented backgrounds, are not graduating from college in STEM fields (Carnevale et al. 2011; National Academies of Science, Engineering, and Medicine 2016). Therefore, bolstering the STEM pipeline by encouraging more students from underrepresented backgrounds to pursue STEM fields is at the forefront of education policy agendas.

Being the point of entry to postsecondary education for 5.7 million undergraduates in the nation, community colleges provide educational opportunities to a large population of students who aspire to enter STEM fields (National Center for Education Statistics 2019). This point is especially relevant in California, home to the largest community college system in the nation. Yet despite the important role community colleges are poised to play in increasing the STEM talent pool, few studies have examined the community college STEM pathway and the relationship between developmental math, a common experience at community colleges, and STEM outcomes. An expansive study examining STEM participation across the California community colleges focused on math course-taking in STEM pathways, but it did not examine how developmental math factored into these pathways (Bahr et al. 2017). Developmental math is an important juncture in STEM pathways as approximately 65% of first-time California community college enrollees start their college trajectory in developmental math (Rodriguez et al. 2017). Although there is significant research on developmental/remedial math on academic outcomes like degree attainment and transfer (see Valentine et al. 2017, for a review), just a few studies have examined whether developmental math affects students' STEM participation (Park and Ngo 2018; Hagedorn and DuBray 2010).

Motivated by the theory that students develop STEM momentum in K-12 schooling and that this momentum waxes or wanes in early college (Wang 2015, 2017), we examine one particular experience during the transition from high school to college called math misalignment. Math misalignment occurs when college students are placed lower in math than expected given their prior high school course-taking achievement and is a consequence of misaligned academic readiness benchmarks between high school and community college (Melguizo and Ngo 2020). For instance, instead of being placed in math courses above algebra 2 in college, students who took algebra 2 or above in high school may place into developmental math and experience math misalignment. Since math is an integral component of STEM pathways in community college (Bahr et al. 2017), math misalignment may halt students' STEM momentum and is therefore a relevant experience for understanding differences in STEM outcomes.

[1] These authors specified that this growth is mostly driven by occupations related to computer and information systems.

We are able to pinpoint experiences of math misalignment by analyzing rich, linked high school to community college transcript data that captures alignment in student-level math course-taking between sectors. We first document the extent to which math misalignment is a barrier for students in STEM pathways. We do so by comparing students who experienced aligned transition with students who experienced math misalignment. Then, we conduct additional analyses to examine whether math misalignment halts students' STEM momentum among STEM-aspiring students who indicated clear STEM interest on their community college enrollment form. The research asks two research questions:

1) Is math misalignment related to students' college math attainment and STEM outcomes?
2) Do these relationships disproportionately affect STEM-aspiring students (i.e., students who intend to major in a STEM field)?

In answering these questions, this study makes several important contributions. First, experiences of math in high school and math course-taking in college significantly factor into STEM momentum and aspirations (Crisp et al. 2009; Wang 2013a, 2015). However, scholars have yet to focus specifically on math misalignment in the community college STEM pathway, a relatively common experience (Melguizo and Ngo 2020).

In addition, our study makes a methodological contribution by outlining the use of high school-by-college fixed effects. This method accounts for the fact that not all students from a particular high school attend the same community college. Therefore, by including these controls we eliminate the unobserved high-school-by-college level variation (Andrews et al. 2006). Unlike prior studies that controlled for selection bias using high school fixed effects, we use high school-by-college fixed effects to control for non-random sorting of students in high schools and in community colleges. Specifically, we identify students with similar skills and backgrounds from the same high school and attending the same college, but due to placement testing results are placed in different math courses. Therefore, we account for any additional unobserved factors due to attending the same high school and college.

To preview our results, we find that a large proportion of students who completed advanced high school math placed in developmental math in community college. Specifically, 53–98% of the students experienced math misalignment, depending on the definition of advanced high school math. Moreover, students who experienced math misalignment were less likely to pass the math requirement for an Associate's degree and attempted and completed fewer transferable STEM courses, with greater observed penalty for students who were misaligned two to three levels below transfer. In particular, we find that math misalignment especially hindered STEM-aspiring students from pursuing STEM fields.

The following section describes prior literature and the study and policy context. We then proceed to discuss the data and the key variables of the study. We present the method used to answer our research questions, report the findings, and conclude with policy implications.

Framework and Prior Literature

STEM Aspirations, Preparation, and Momentum

Conceptually, our study builds upon the literature on STEM aspirations, preparation, and momentum and their relationship to STEM outcomes. Several studies found that a key factor in ushering students into STEM fields is students' STEM aspirations (Maltese and Tai 2011; Tai et al. 2006; Wang 2013a, b). Students' STEM aspirations are regarded as a key driving force behind actions that are conducive to persisting in STEM (Lent et al. 2003; Maltese and Tai 2011). In developing students' aspirations, studies highlight the importance of high school math and science exposure and building students' self-efficacy through evidence of early achievement in STEM subjects (Wang 2013a, b). Subsequently, students' aspirations and preparation feed into building students' STEM momentum.

The concept of STEM momentum provides a framework for examining who enters and attrits from STEM pathways during the transition to college. STEM momentum is defined as "academic behaviors and efforts students exhibit in early STEM coursework that propel them forward towards persistence and success in STEM fields of study" (Wang 2015, p. 377). According to this concept, students sustain STEM momentum, which is composed of and affected by individual and environmental characteristics, from high school to postsecondary education along three specific domains: the curricular domain, the motivational domain, and the teaching and learning domain (Wang 2017). In this study, we focus on the curricular domain of STEM momentum, and specifically, the opportunity for students to maintain forward momentum in coursework and progress through the course sequence. We also note that the experience of math misalignment influences the curricular experiences by leading to potential confusion, ill-structured path of courses, and thus may have implications for the motivational domain of STEM momentum. Overall, this model also emphasizes experiences that produce friction to STEM momentum, such as when students face financial barriers, unclear pathways, and inadequate advising. We focus on one potential barrier to STEM momentum: the lack of clear pathways aligned with students' intent, as evidenced by math misalignment.

In addition to molding aspirations and feeding into STEM momentum, STEM high school performance measures are also regarded as demonstrations of academic readiness. Academic readiness is "the preparation required to enroll in college and persist to graduation without need for remediation" (Duncheon 2015, p. 10). Academic readiness is often operationalized by indicators like HS GPA, prior course-taking, freshman GPA, and the avoidance of remedial work (Klasik and Strayhorn 2018; Porter and Polikoff 2012). We focus on the mismatch between HS GPA and advanced math course-taking (i.e., two benchmarks of readiness in high school), and community college math placement (i.e., a benchmark of readiness in college), as they relate to promoting or halting students' momentum in STEM pathways.

Math Misalignment and Developmental Education

Math misalignment may be particularly relevant for understanding postsecondary STEM attainment because, as described above, math course-taking experiences are integral to STEM momentum. In contrast to examining the influence of high school math course-taking on postsecondary coursework and labor market outcomes (e.g., Goodman 2019), or remedial course-taking and majoring in STEM fields in college (e.g., Crisp et al. 2009), math misalignment characterizes students' math placement as a more nuanced experience by linking college math placement to high school performance measures. This nuance is important because, in theory, students who are deemed "college-ready" by high school benchmarks should not need remediation in community college; they should progress forward in their math course-taking.

However, upward transition between institutions is not seamless as students must take the placement test to enroll in community college and the test score determines the courses they are eligible to take once they enroll. From the students' perspective, they most likely enter college believing they are ready to take on college-level coursework given their academic success in high school. Yet, nearly 70% of students in community colleges report taking a developmental/remedial course in math or English (Chen 2016). This experience may largely be the consequence of mismatch in readiness standards across sectors and colleges (Ngo et al. 2018). For example, in California, prior to 2017, California community colleges used placement tests to assess students' math skills, with significant variation across campuses (Melguizo et al. 2014; Rodriguez et al. 2016). Case in point, a survey of colleges revealed that colleges' math cut scores for the ACCUPLACER placement test ranged from 25 to 96 depending on the campus, suggesting that students are placed in different levels conditional on where they attend (Rodriguez et al. 2016). In addition, studies estimate that a sizeable percentage of students—as many as one-quarter of math students—may be placed in error into lower-level courses and that misplacement is detrimental to students' academic success (Melguizo and Ngo 2020; Scott-Clayton et al. 2014). Thus, math misalignment may be the direct consequence of problems associated with placement testing and the mismatch in college-readiness standards between high schools and community colleges (Melguizo and Ngo 2020).

In response to these concerns, states have been engaging in a number of reforms in developmental education specifically focused on the assessment and placement process (Scott-Clayton 2018). For example, Florida's public colleges have moved away from reliance on placement testing by making developmental education optional (Hu et al. 2015). The California Community College system has expanded its use of multiple measures under Assembly Bill 705 (AB 705), requiring all colleges to place students using measures like high school math course-taking records and high school GPA (Burks 2017; Rodriguez et al. 2018). The shift to using high school measures in lieu of placement tests to place students into developmental courses under AB 705 should reduce math misalignment, though the impact of the reform remains yet to be seen.

Implications for STEM

As research suggests math is an important juncture in all STEM fields (Bahr et al. 2017), the experience of being placed in a misaligned math course may contribute to differences in STEM outcomes. Indeed, there are a number of studies linking math course-taking to STEM participation and attainment. For example, studies show that students who took advanced math coursework are less likely to drop out, more likely to persist in college (Adelman 2006), and more likely to pursue STEM fields (Goodman 2019).

Although a large proportion of students begin their community college journey in developmental math, there is less research examining how developmental math factors into STEM pathways in community college. Since the majority of the students begin their college journey in developmental math, whether math misalignment serves as a diversion or counter-momentum friction from pursuing and persisting in STEM pathways is an important, unanswered question that this study aims to investigate. As Wang (2017) pointed out, community college students face considerable counter-momentum friction that erode at the STEM momentum accumulated in high school. We identify math misalignment as one counter-momentum friction that may be particularly consequential for STEM-aspiring students. Overall, our goals are to identify the consequences of math misalignment and examine the implications of this misalignment for a population of STEM-aspiring high school students making the transition to community college.

Data and Context

The data used in this study are linked longitudinal transcript data obtained through partnerships with a Large Urban School District (LUSD) and a Large Urban Community College District (LUCCD) in the same metropolitan area in California. This rich longitudinal data include students' complete high school and community college transcript data, demographic information, and placement test score information and outcomes through 2016. The sample consists of 45,333 LUSD students who enrolled in one of the LUCCD colleges during 2009–2014 and within 3 years of graduation. We excluded students who are concurrent high school students and students with no known high school course-taking and math placement information. From our initial number of 45,333 students, we identified 8743 (19%) STEM-aspiring students who indicated interest in pursuing a STEM field on the college enrollment form.

Both the high school and community college districts in this study are extremely diverse socioeconomically and racially. The schools and colleges in this district educate over 225,000 students each year in which the majority are identified as socioeconomically disadvantaged, students of color, and/or categorized as English Learners. Being the local community college district, about 40–45% of LUSD graduates enroll in the LUCCD each year. Serving a large population of minoritized students, these two districts are relevant spaces for the analyses on diversifying and increasing the STEM talent pool.[2]

The context is also one with considerable math misalignment due to the use of placement testing. During the timeframe of our study, most California community colleges used some form of math placement test to place students into math courses (Rodriguez et al. 2016). In LUCCD these included such instruments as ACCUPLACER, Compass, or Mathematics Diagnostic Testing Project (MDTP). Furthermore, students could be awarded a few additional points based on their academic achievement and preparation, such as a high GPA and/or taking advanced math courses in high school (Ngo and Kwon 2015; Rodriguez et al. 2016). Nevertheless, the use of these multiple measures was modest, and placement test scores by and large played the largest role in determining college placement in the district and at virtually all California community colleges (Rodriguez et al. 2016).

[2] Aligning with the California state graduation requirements, LUSD students are required to complete at least 3 years of math and 2 years of science courses to obtain a high school diploma (California Department of Education 2018). At LUCCD, students are required to pass intermediate algebra (algebra 2 equivalent) with a C or higher in order to obtain an Associate's degree. However, in order to transfer to a California State University (CSU) or a University of California (UC) in one of the STEM majors, students must complete 60 semester units or 90 quarter units. This information was obtained through the assist.org website. The specific criteria vary depending on the major. For example, to transfer with a Biology major, students need 40 major-specific units and in Biochemistry, students need 44 major-specific units.

Key Variables

Before describing the methods, we explain below how we operationalize the main explanatory variables: STEM-aspiring and math misalignment.

STEM-Aspiring

STEM-aspiring students are LUSD graduates who indicated that they intend to major in one of the STEM fields in their college application. The LUCCD transcript data include the name of the major as well as the corresponding Taxonomy of Program (TOP) code. The TOP code represents numerical codes used at the state level to align local programs into similar program categories. The U.S. Department of Education classifies different majors and programs using the Classification of Instructional Programs (CIP) code. We use a crosswalk of TOP codes and CIP codes published by the California Community College Chancellor's Office (2004) and Wang's (2016) study on community college STEM pathways to classify different majors as STEM or non-STEM. Appendix Table 6 shows the crosswalk of the name of the program at the college, the TOP codes, and the two-digit CIP codes implemented in this study.

Definitions of Math Misalignment

We disaggregate students' math placement levels by prior math course-taking achievement. We make the distinction between remediation and misalignment because indicators of remediation are predominantly based on college standards and do not incorporate high school math proficiency in a meaningful way. For example, a remediation-based analysis might consider all students placed in intermediate algebra (algebra 2 equivalent) as having the same academic preparation and level of readiness for college mathematics. However, a misalignment-based analysis would distinguish students who placed in remediation by evidence of prior achievement in high school math (Melguizo and Ngo 2020).

Table 1 displays our three definitions of math alignment. In the first three rows, we define math misalignment based solely on course-taking in high school. According to our first definition, students experience math misalignment if they passed algebra 2, pre-calculus, or calculus in high school and placed in intermediate algebra (algebra 2 equivalent) or below in college. In other words, students do not experience math misalignment if they passed high school algebra 2 or higher and placed in transfer-level math in college. Since students completing algebra 2, pre-calculus, or calculus in high school are expected to progress to transfer-level math in college, we separate these analyses by highest level of math completed. Transfer-level math courses are college-level math course that are accepted by the University of California (UC) and the California State University (CSU).

The second definition of misalignment is based on overall grades (GPA), and the third incorporates both grades and math course-taking. The second and third definitions are derived from the rules developed for a recent legislation passed in California, AB 705, that mandates the use of high school records to place community college students (Bahr et al. 2019; Research and Planning Group [RP Group] 2018). In light of recent validation study that found high school GPA as the best predictor of readiness to undertake college-level coursework in math and English (Bahr et al. 2019), we define misalignment using students' high school GPA. We conduct an exercise using these additional definitions in order to

Table 1 Definition of misalignment based on the highest high school math course, HS GPA, and math placement

High school math experience	Math placement in college				
	Transfer	Int. Alg	Elem Alg	Pre-Alg. and below	N
All LUSD-LUCCD students					
Highest HS Math = Algebra 2	2%	22%	28%	**48%**	18,176
Highest HS Math = Pre-Calculus	15%	**35%**	22%	29%	8,095
Highest HS Math = Calculus	**47%**	33%	9%	12%	1429
HS GPA ≥ 3.0	18%	**32%**	21%	29%	7321
HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took Calculus	31%	**34%**	14%	20%	3046
STEM-aspiring students					
Highest HS Math = Algebra 2	3%	23%	27%	**47%**	3,414
Highest HS Math = Pre-Calculus	18%	**35%**	20%	27%	2,062
Highest HS Math = Calculus	**54%**	29%	6%	12%	546
HS GPA ≥ 3.0	25%	**31%**	17%	27%	1,920
HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took Calculus	**40%**	32%	10%	19%	971

Each row is a sub-sample based on the placement criteria and STEM aspiration. The row percentages add to 100%. Bold values indicates the highest percentage within each row. Transfer = alignment. Int. Alg = intermediate algebra (algebra 2 equivalent), Elem. Alg. = elementary algebra, Pre-alg. and below = pre-algebra and below

gain insight into how such rules might affect students in STEM pathways under AB 705.[3] The second definition is recommended for students undertaking the Non-STEM pathways while, the third definition, which draws from a combination of course-taking and GPA, is relevant for STEM-aspiring students attending a California community college. According to AB 705, students who intend to major in STEM must either have at least a 3.4 HS GPA or at least a 2.6 HS GPA and have enrolled in calculus in order to directly place in transfer-level math without additional math support. We examine the STEM outcomes of students meeting these criteria to see how the proposed definitions might influence community college STEM participation. Appendix Table 7 shows how the samples overlap depending on the misalignment criteria.

It is important to note that while we derive the last two definitions based on the new policy, the use of HS GPA and course-taking are part of a broad set of multiple measures that were already used by many colleges before AB 705 (Ngo and Kwon 2015). The difference with the passage of AB 705 is that colleges will now determine placement mainly using multiple measures instead of regarding multiple measures as supplemental indicators. Nonetheless, these benchmarks outline criteria by which students should be able to progress in math between high school and college, and therefore offer policy-relevant ways of defining misalignment.

To examine groups of students who met each math misalignment definition, we create five separate sub-samples that fit under these definitions as shown in Table 1. The first

[3] These parameters resulted from a suit of validation studies conducted by the research arm of the Chancellor's Office (Bahr et al. 2019; Research and Planning Group 2018). The Chancellor's Office provided this set of default placement rules if colleges wish to bypass their own AB 705 validation efforts.

definition includes 18,176 students who passed algebra 2, 8,095 students who passed pre-calculus, or 1,429 students who passed calculus. The second definition includes 7321 students with at least 3.0 HS GPA and finally, the third definition includes 3046 students who have at least a 3.4 HS GPA or at least a 2.6 HS GPA and took calculus. Since students could be placed far below transfer-level math, the "aligned" course, the misalignment indicator is not dichotomous but a degree.

Table 1 displays the distribution of math placement among all students and STEM-aspiring students. We cross-tabulate students' highest high school math course with college math placement. Table 1 indicates that, irrespective of the math misalignment definition, less than 50% of the students experienced alignment, with students experiencing increased severity of misalignment the farther they are from taking calculus (i.e., algebra 2). The grey cells highlight the most common placement within each row. For example, the most common math placement among students who took algebra 2 was pre-algebra (48%). On the other hand, among students who took pre-calculus or with at least a 3.0 HS GPA, the most common math placement was intermediate algebra (algebra 2 equivalent). The most common math placement among students who took high school calculus was transfer-level math (47%). Depending on the definition, 53–98% of the students experienced misalignment.

While the specific percentages differ, the pattern that we see in all students is also apparent in the STEM-aspiring sample. Specifically, very few STEM-aspiring students (3%) placed in transfer-level math if algebra 2 was their highest math enrollment in high school. In fact, half of all STEM-aspiring students whose highest high school math was algebra 2 placed in the lowest math level in college (pre-algebra and below). Even when we examine STEM-aspiring students with at least a 3.0 HS GPA or who took high school pre-calculus, most placed into intermediate algebra (algebra 2 equivalent) or below in college.

Method

To answer our two research questions, we estimate the following models with high school-by-college and cohort fixed effects:

$$y_{ist} = \beta_0 + \sum_{n=1}^{4} \beta_n MM_{i,n} + X'\beta + \tau_s + \pi_t + \varepsilon_{ist} \quad (1)$$

$$y_{ist} = \beta_0 + \sum_{n=1}^{4} \beta_n MM_{i,n} + \beta_5 STEM_i + \sum_{n=6}^{9} \beta_n MM_{i,n} * STEM_i + X'\beta + \tau_s + \pi_t + \varepsilon_{ist} \quad (2)$$

where, y_i represents STEM outcomes (detailed below) for student i in the same high school to college feeder pathway s in cohort t. The variable $MM_{i,n}$ is a series of dummy variables referring to the degree of math misalignment based on the three definitions under Table 1, with alignment as the omitted/base category. $\boldsymbol{X}$ is a set of control variables including: gender, race, special education status, whether the student lives within the district zone, whether or not students intend to transfer or complete an Associate's degree, English learner status, and citizenship status. Importantly, we also include academic background variables that can account for differences in academic preparation among aligned and misaligned students. These variables include whether they took an honors or AP course, HS GPA, math and science state standardized test scores,[4] and taking AP math and science courses. τ_s refers to high school-by-college fixed effects and π_t refers to cohort fixed effects.

In Eq. 1, we estimate the relationship between each degree of math misalignment and STEM outcomes for all students in the sample. In Eq. 2, we include an interaction between the math misalignment variable and a dichotomous indicator of STEM aspiration, $STEM_i$. These interactions allow us to identify whether the experience of misalignment differentially affects students in STEM pathways.

Identification

Most STEM-related studies on the transition from high school to college estimated regression or logistic regression without school fixed effects (e.g., Riegle-Crumb and King 2010; Riegle-Crumb et al. 2012; Tai et al. 2006; Wang 2013a). However, students' STEM-course-taking patterns and their subsequent likelihood of STEM participation in college differ depending on the high school students attend (Gottfried and Bozick 2016). For example, some high schools may put a premium on STEM education and that may impact students' aspirations to pursue STEM fields. Schools are not randomly assigned and thus the notion that the school-level measures are independent of student-level factors is a strong assumption. Also, students attending the same schools may have correlated errors (unobserved similar characteristics); therefore, it is preferable to compare students who come from the same high school.

However, there are two methodological complexities unique to this study. The first consideration is that students who graduated from the same high school can attend different LUCCD colleges. Thus, there may be unobserved correlation due to attending the same college and also due to attending the same high school. In other words, the within-high-school estimation (i.e., high school fixed effects) does not entirely correct for selection bias due to non-random sorting among students from the same high school into different colleges (e.g., Andrews et al. 2006; Rabe-Hesketh and Skrondal 2012). This issue can be addressed by including high-school-by-college fixed effects. The high-school-by-college fixed effects removes any high-school-by-college level variation. By doing so, students in one college who come from the same high school are compared with others who also fit that criteria. Therefore, we use high-school-by-college fixed effects as our analytical approach because community colleges draw students from a range of high schools and vice versa.

Additionally, we include cohort dummies to remove any correlation due to being part of the same cohort. For example, it could be that students in one cohort are more motivated than others or that some students who were part of a cohort of high school graduates during the 2008 Great Recession may have entered higher education at a higher rate than the later cohorts. Therefore, the high-school-by-college fixed effects with cohort dummies is

[4] Prior to 2014, all students in grades 9 through 11 were required to take the math and science California State Tests (CST) if they attend a California public school. The state set five performance level on the CST based on a range of cut scores, and they are: advanced, proficient, basic, below basic, and far below basic. In 2014–15, California implemented a new testing scheme aligned to the Common Core State Standards. The data used in this study cuts off at 2014. We include students' CST scores in math and science as well covariates capturing the math and science course taken in 10th and 11th because the CST tests students take directly corresponds to their course.

the preferred estimation. All analyses include high school-by-college cluster robust standard errors (Bertrand et al. 2004). In short, we estimate the relationship between math misalignment and STEM outcomes for students in the same feeder pathways.

STEM Outcome Measures

Our outcomes of interest are the number of transferable math and transferable STEM credits completed within 2 years of enrollment and the number of transferable STEM units completed overall.[5] To create these measures, we needed to first identify math and STEM courses. We exported out all possible course names listed in the enrollment records. Then we referenced the college websites and course catalogs to check whether each course name and course number combinations count as transferable math or science courses. Next, we devised a set of rules that lists the math and science courses that count for transfer and flagged the appropriate course name in the data. Transferable units are defined as units that are accepted in the UC or the CSU.

The number of transferable STEM units completed are indicative of the extent to which students have persevered in STEM courses. Previous studies have examined whether or not students declared a STEM major at the start of college (Crisp et al. 2009; Gottfried and Bozick 2016; Riegle-Crumb and King 2010) and other studies have studied bachelor's degree attainment or transfer (Wang 2015; Wang et al. 2017). While bachelor's degree attainment and majoring in STEM fields are important milestones, outcomes like accumulating enough transferable STEM credits for transfer are important intermediary milestones in the community college setting. A recent report by a research arm of the California Community College Chancellor's Office pointed out that not all students who transferred did so with an Associate's degree and among students with enough credits to transfer, a significant number of students did not complete an Associate's degree (Research and Planning Group 2017). Therefore, this study focuses on intermediary outcomes like accumulating enough transferable STEM units necessary for STEM transfer.

Missing Values

There are different amounts of missing values depending on the covariate. Most of the covariates have minor missing values and the missing values are assumed to be random coding error (see Appendix Table 8 for more information on missing data). Thus, we flag missing values with an extra indicator identifying which observations on that variable have missing values (Allison 2002).[6] For high school GPA, we impute missing values with the mean value. Given the small number of missing values on HS GPA (n = 56) we found that the results are nearly identical to ones without imputing for missing values.

[5] We identified completing transferable credits within 2 years of enrollment as a relevant timeframe because community colleges, in spirit, offer 2-year programs leading to an associate's degree or transfer. According to the California Master Plan for Higher Education, community colleges in California are supposed to provide education during the first 2 years of undergraduate education (University of California Office of the President n.d.). Since the establishment of the plan, however, research suggests that students exhibit erratic enrollment patters and tend to remain enrolled for longer than 2 years (e.g., Crosta 2014). For this reason, we also examine the total number of STEM credits completed overall.

[6] All missing values except HS GPAs are imputed with a zero and included with the extra dummy indicator in all specifications.

Table 2 Sample statistics

	(1)		(2)	
	LUSD-LUCCD students[a]		STEM-aspiring students[b]	
	Mean or %	SD	Mean or %	SD
Demographic and academic indicators				
Female	51%			55%
Asian	7%			11%
Black	9%			8%
Hispanic	71%			68%
White	7%			7%
Other[c]	6%			6%
Special education	12%			10%
English learner categorization	14%			12%
Honors or AP	7%			11%
Years of A-G Math	2.85	0.90	2.95	0.90
Years of A-G Science	2.19	0.92	2.31	0.93
11th Grade Math CST Score	273.94	48.25	283.08	53.23
11th Grade Science CST Score	303.34	41.69	311.68	44.84
Cumulative HS GPA	2.39	0.61	2.49	0.63
Number of non-AP advanced math	2.18	1.99	2.62	2.15
Number of AP math or science	0.23	0.83	0.40	1.12
Placed in Transfer Level Math	5%		9%	9%
Transfer or AA Intent[d]	62%		63%	63%
STEM-Aspiring	19%		–	
N	45,333		8,743	

Students who entered college between 2009–2014 and who are not concurrent high school students are included in these samples. Also, students who have not taken any math course in high school and do not have math placement information are not included in the sample

[a]All students in the 2009–2014 cohort

[b]Students in the 2009–2014 cohort who indicated that they would like to pursue a STEM major, defined as either life science or physical science/engineering

[c]Students who declined to state, or unknown race

[d]Indicator of students' educational goals at the start of college

Results

Descriptive Statistics

Table 2 below shows how the sample of LUSD-LUCCD students (column 1) compares to STEM-aspiring students (column 2) along various demographic and course-taking measures. There are several interesting trends evident in Table 2. Over 75% of students in either sample are URMs, with the majority being Latina/o students. In the larger LUSD-LUCCD sample, 12% have special education designations, but fewer percentage (i.e., 10%) of STEM-aspiring students are identified as special education.

Students' high school course-taking measures also paint a nuanced picture of the two samples. Notably, STEM-aspiring students, on average, have stronger academic preparation than the full LUSD-LUCCD sample, having taken more math and science courses, earning higher HS GPAs, and receiving higher scores on the math and science state standardized tests. Therefore, STEM-aspiring students perform better on high school measures compared to the full sample of LUSD-LUCCD students.

Math Misalignment and STEM Outcomes

In Table 3, we display the relationship between the degree of math misalignment on passing intermediate algebra and attempting and completing transferable STEM units for students in the same high school to community college feeder pathways.

We find that community college students who experienced varying degrees of math misalignment completed fewer transferable math and STEM courses than those who experienced alignment. These relationships held irrespective of the alignment criteria. Among those who completed algebra 2, students who placed in intermediate algebra (algebra 2 equivalent) completed two fewer math credits within 2 years of enrollment and four fewer STEM credits overall compared to students who placed directly in transfer-level math. Exhibiting stronger high school math preparation did not buffer against the experience of misalignment. Among those who completed calculus, students who experienced math misalignment completed two fewer math units and six fewer transferable STEM units compared to students who placed directly in transfer-level math. Among students who completed calculus, if they placed in pre-algebra or below, they completed eleven fewer transferable STEM units compared to students who placed directly in transfer-level math. These effects are prevalent among those from the same high school to community college feeder pathways and after accounting for racial, gender, and socioeconomic variation.

In short, the experience of math misalignment is strongly and negatively associated with STEM outcomes for all entering community college students. Next, we also investigate whether these results differ if students display STEM aspiration.

Results for STEM-Aspiring Students

Table 4 examines whether the degree of misalignment on STEM attainment within 2 years of enrollment is moderated by STEM aspiration and Table 5 examines whether the degree of misalignment on STEM outcomes overall is moderated by STEM aspiration. Again, these are students who indicated a STEM major on their college enrollment form. Table 4 shows that there is a significant negative interaction effect for students who took algebra 2 or pre-calculus as their highest high school math or had at least a 3.0 HS GPA. Specifically, Table 4 indicates that math misalignment is associated with a decreased likelihood of completing transferable math and STEM units within 2 years of enrollment particularly for STEM-aspiring students compared to STEM-aspiring students who were not misaligned. For example, in column 5, we find that STEM-aspiring students who repeated algebra 2 completed four fewer transferable STEM units within 2 years of enrollment than those who placed directly in transfer-level math (i.e., – 1.78–2.29). The general insignificant interaction results when examining students who took calculus suggest that STEM-aspiring students were similarly hindered by misalignment as their non-STEM-aspiring peers (see column 3).

Table 3 High school-by-college fixed effects estimation of math misalignment on STEM outcomes

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Transferable math units completed in 2 Years					
Misaligned one level below/placed in IA	−1.88***	−2.04***	−2.30***	−2.34***	−2.31***
	(0.15)	(0.22)	(0.41)	(0.19)	(0.27)
Misaligned two levels below/placed in EA	−2.11***	−2.49***	−3.32***	−2.78***	−3.18***
	(0.15)	(0.23)	(0.65)	(0.21)	(0.31)
Misaligned three levels below/placed in Pre-alg. & below	−2.24***	−2.59***	−2.33**	−3.06***	−2.99***
	(0.15)	(0.25)	(0.87)	(0.23)	(0.39)
Transferable STEM units completed in 2 Years					
Misaligned one level below/placed in IA	−2.62***	−3.33***	−3.09***	−3.79***	−2.96***
	(0.40)	(0.47)	(0.85)	(0.44)	(0.59)
Misaligned two levels below/placed in EA	−3.16***	−4.06***	−5.04***	−4.84***	−5.02***
	(0.42)	(0.49)	(1.25)	(0.48)	(0.64)
Misaligned three levels below/placed in Pre-alg. & below	−3.58***	−4.36***	−3.28	−5.33***	−4.91***
	(0.42)	(0.51)	(1.74)	(0.55)	(0.95)
Transferable STEM units completed					
Misaligned one level below/placed in IA	−3.87***	−4.16***	−5.81***	−4.70***	−4.20***
	(0.87)	(0.66)	(1.71)	(0.75)	(1.13)
Misaligned two levels below/placed in EA	−5.11***	−5.87***	−10.34***	−6.77***	−8.90***
	(0.90)	(0.68)	(1.78)	(0.74)	(1.14)
Misaligned three levels below/placed in Pre-alg. & below	−5.77***	−6.24***	−10.91***	−7.96***	−9.29***
	(0.88)	(0.72)	(2.55)	(0.82)	(1.33)

Table 3 (continued)

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Number of high school by college clusters	648	426	207	420	286
Number of students	18,176	8095	1429	7321	3046

All estimation includes the following covariates: gender, race, whether or not the student lives within the school district, students' primary language, whether or not the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associates degree, whether students took AP or honors courses in high school, HS GPA (except when HS GPA is the math misalignment criteria), 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

IA intermediate algebra, *EA* elementary algebra

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Similar to the results shown in Table 4, the results on the overall completion of transferable STEM units paints a similar picture. Specifically, STEM-aspiring students, on average, attempted significantly more STEM courses than non-STEM-aspiring students. However, STEM-aspiring students were disproportionately less likely to complete transferable STEM units than their STEM-aspiring peers who experienced alignment, evidenced by the statistically significant negative interaction terms. This finding held across all misalignment definitions. For example, as shown in Table 5, column 5, STEM-aspiring students who experienced alignment attempted about 12 more STEM units overall than STEM-aspiring peers who were misaligned three levels below (i.e., − 6.77–4.73). Thus, STEM-aspiring students who experienced severe math misalignment were much less likely to attempt and complete transferable STEM courses than similar STEM-aspiring students who experienced alignment.

Graphical Representation of the Findings

Next, we present graphical representation of the findings under one of the multiple measure criteria most relevant to STEM-aspiring students according to AB 705: indication of graduating with at least a 3.4 HS GPA or having taken calculus. Figure 1, below, shows the results for STEM-aspiring students on the number of STEM credits completed within 2 years of enrollment and overall.

Corresponding to the results in Tables 4 and 5, Fig. 1 shows that STEM-aspiring students, on average, completed more transferable STEM courses than non-STEM-aspiring students. However, the steeper downward slopes for STEM-aspiring students indicate that these students were more negatively affected by the experience of misalignment. In addition, the gap we observe in 2 years of enrollment persists when we examine overall outcome. Corresponding to the results in Table 5, the graph shows that STEM-aspiring students who experienced alignment completed six to eleven more transferable STEM units overall compared to STEM-aspiring students who experienced varying degrees of math misalignment.

Sensitivity Analyses

We conduct four sensitivity analyses to check whether the results are sensitive to how math misalignment is specified. First, we re-specify the multiple measure indicators based on students' last high school math course passed instead of students' highest high school math course since some students may not take any math course during the last year of high school or may take an easier math course during 12th grade compared to 11th grade. Second, we examine math enrollment instead of placement and use the same estimation strategy because students may not comply with their math placement, may decide to not enroll at all, or delay their enrollment after receiving their math placement results. Third, we restrict our main specification—using highest high school math—to students who received an A or a B in their course grades.

Appendix Tables 9 and 10 show the results examining the misalignment between students' last math course and math placement. Appendix Tables 11 and 12 show the results examining the misalignment between students' highest high school math course and math enrollment. Appendix Tables 13 and 14 show the results examining the misalignment

Table 4 Interaction estimation of math misalignment and STEM aspiration on STEM participation within 2 Years

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Transferable math units completed, 2 Years					
STEM-aspiring	1.65**	1.55***	1.96***	2.05***	2.65***
	(0.51)	(0.37)	(0.55)	(0.36)	(0.41)
Misaligned one level below	− 1.54***	− 1.68***	− 2.25***	− 1.82***	− 1.72***
	(0.17)	(0.21)	(0.43)	(0.20)	(0.28)
Misaligned two levels below	− 1.72***	− 2.10***	− 3.05***	− 2.22***	− 2.46***
	(0.17)	(0.23)	(0.72)	(0.24)	(0.35)
Misaligned three levels below	− 1.84***	− 2.20***	− 2.20**	− 2.53***	− 2.31***
	(0.17)	(0.25)	(0.78)	(0.25)	(0.38)
Misaligned one level below X STEM-aspiring	− 1.27*	− 1.03**	0.26	− 1.48***	− 1.32*
	(0.54)	(0.40)	(0.80)	(0.39)	(0.57)
Misaligned two levels below X STEM-aspiring	− 1.49**	− 1.12**	− 0.19	− 1.69***	− 1.85**
	(0.50)	(0.37)	(1.39)	(0.42)	(0.57)
Misaligned three levels below X STEM-aspiring	− 1.56**	− 1.15**	0.50	− 1.54***	− 1.68**
	(0.51)	(0.40)	(1.19)	(0.39)	(0.57)
Transferable STEM units completed, 2 Years					
STEM-aspiring	3.78***	4.80***	6.32***	6.16***	7.28***
	(0.98)	(0.79)	(0.92)	(0.63)	(0.72)
Misaligned one level below	− 2.17***	− 2.64***	− 2.90***	− 2.62***	− 1.78**
	(0.49)	(0.40)	(0.86)	(0.45)	(0.61)
Misaligned two levels below	− 2.59***	− 3.20***	− 3.56**	− 3.49***	− 3.45***
	(0.51)	(0.47)	(1.34)	(0.56)	(0.72)
Misaligned three levels below	− 2.80***	− 3.36***	− 3.08	− 3.98***	− 3.68***
	(0.51)	(0.50)	(1.63)	(0.58)	(0.92)

Table 4 (continued)

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Misaligned one level below X STEM-aspiring	− 1.31	− 1.60	0.82	− 2.97***	− 2.29*
	(1.07)	(0.87)	(1.82)	(0.76)	(1.12)
Misaligned two levels below X STEM-aspiring	− 1.79	− 2.15*	− 2.91	− 3.83***	− 3.49**
	(0.97)	(0.87)	(2.40)	(0.80)	(1.23)
Misaligned three levels below X STEM-aspiring	− 2.88**	− 2.73**	2.31	− 3.75***	− 2.31*
	(0.98)	(0.91)	(2.13)	(0.70)	(1.02)
Number of high school by college clusters	648	426	207	420	286
Number of students	18,176	8095	1429	7321	3046

STEM-aspiring is a dichotomous variable indicating students who intend to pursue a STEM major on their college application. The outcome is observed within 2 years of first enrollment in community college. All estimation includes the following covariates: gender, race, whether the student lives within the school district, students' primary language, whether the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associate's degree, whether students took AP or honors courses in high school, HS GPA, 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 5 Interaction estimation of math misalignment and STEM aspiration on STEM outcomes

Transferable STEM units completed	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took Calculus
STEM-aspiring	10.18***	11.44***	13.34***	14.32***	15.20***
	(1.86)	(1.16)	(1.79)	(1.04)	(1.21)
Misaligned one level below	−2.48**	−2.42***	−4.69**	−2.33***	−1.96
	(0.75)	(0.62)	(1.59)	(0.65)	(1.11)
Misaligned two levels below	−3.39***	−3.92***	−7.48***	−3.85***	−6.06***
	(0.75)	(0.70)	(1.81)	(0.73)	(1.13)
Misaligned three levels below	−3.78***	−4.11***	−9.14***	−5.16***	−6.77***
	(0.75)	(0.77)	(2.49)	(0.76)	(1.32)
Misaligned one level below X STEM-aspiring	−4.35*	−4.19**	−0.35	−5.63***	−4.05*
	(1.92)	(1.31)	(3.11)	(1.14)	(1.68)
Misaligned two levels below X STEM-aspiring	−5.70**	−4.70***	−4.92	−8.14***	−5.38*
	(1.80)	(1.33)	(2.99)	(1.46)	(2.53)
Misaligned three levels below X STEM-aspiring	−7.06***	−5.33***	0.31	−7.33***	−4.73**
	(1.91)	(1.45)	(2.92)	(1.27)	(1.65)
Number of high school by college clusters	648	426	207	420	286
Number of students	18,176	8095	1429	7321	3046

STEM-aspiring is a dichotomous variable indicating students who intend to pursue a STEM major in their college application. The outcome is observed within 2 years of first enrollment in community college. All estimation includes the following covariates: gender, race, whether the student lives within the school district, students' primary language, whether the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associate's degree, whether students took AP or honors courses in high school, HS GPA, 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

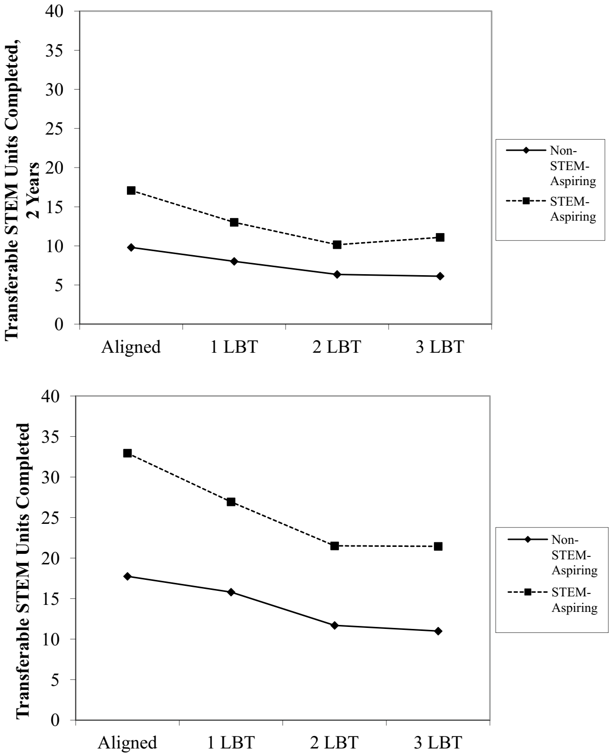

Fig. 1 Adjusted means of transferable STEM units completed by STEM-Aspiration. STEM-aspiring refers to students who declared a STEM major in their college application. Non-STEM-aspiring refers to all other students, both undecided and non-STEM majors

between students' highest high school math course passed with an A or a B and math placement.

All of the main results are robust and qualitatively similar to the various specifications of misalignment. Irrespective of how we redefine misalignment, students who experienced varying degrees of math misalignment were less likely to successfully complete transferable math and STEM courses. Corroborating our main results, the math misalignment penalty was larger for STEM-aspiring students than non-STEM aspiring students. This helps to confirm our hypothesis that math misalignment is a consequential experience in the STEM pathway particularly for STEM-aspiring students.

Discussion

Using a linked dataset of students' high school and community college records, we identified the experience of math misalignment using three different definitions and explored the relationship between math misalignment and college STEM outcomes. We also focused our analysis on STEM-aspiring students who entered community college with an intent to major in a STEM field. We found a significant mismatch between students' high school math achievement and community college math placement; 53–98% of the students experienced math misalignment depending on the definition. In addition, we found that students who experienced math misalignment completed fewer transferable math and STEM courses, with greater observed penalty for students who were misaligned two to three levels below transfer.

This study adds new evidence to the existing literature on developmental education, namely, that it is a context that creates experiences of math misalignment, which in turn has negative implications for academic achievement. The math misalignment penalty was especially salient for STEM-aspiring students, who were more deterred from key STEM milestones than their peers. In this regard, math misalignment hindered the very students with the greatest STEM interest.

The findings suggest that the experience of math misalignment is consequential for STEM momentum. Given that a typical STEM course is about three to five units, the magnitude of the results translates to completing two to three fewer transferable STEM courses due to math misalignment. This is a concern because studies note that students who begin their STEM education at community colleges are most successful in transferring to a 4-year university if they accumulate significant STEM credits during the first year of college (Wang 2015). In fact, the most common course-taking pattern of students who successfully transfer is accumulating at least three transferable STEM units during their first-term in community college (Wang 2016). In light of these findings, the misalignment penalty is akin to "starting off on the wrong foot"—STEM-aspiring students who experienced math misalignment faced the burden of rectifying a bad start.

One explanation behind why math misalignment disproportionately affects STEM-aspiring students may be related to curricular structures. STEM-aspiring students are more likely to need to take STEM courses that have pre-requisites or co-requisites of advanced math (e.g., trigonometry or calculus requirements for engineering and physics courses), whereas non-STEM-aspiring students can choose among a wider range of STEM courses that do not have these requirements. The experience of math misalignment may therefore be more deleterious to the STEM progress of STEM-aspiring students because their ability to progress in STEM pathways depends on timely entry into and completion of transfer-level math courses.

Although we are not able to examine student motivation with the data, another possible explanation for the differences we observed among STEM-aspiring students is related to the motivational dimension of the STEM momentum framework. STEM-aspiring students who placed lower than they expected may have received conflicting messages about their academic ability to perform well in STEM subjects. It may be that students received one message about their level of academic preparedness in high school and a different message from their math placement results in college. Particularly for STEM-aspiring students who took advanced high school math like pre-calculus or calculus, placing in pre-algebra or below in college sends a conflicting signal about their fit and potential to succeed in STEM courses. Indeed, unexpectedly finding one's self in a math course that is at a lower level than expected based on high school preparation may have significant psychic costs. Stinebrickner and Stinebrickner (2012, 2014) showed that early feedback in college in the form of grades led students to evaluate their abilities and potential, and this had implications for choosing STEM majors (2014) and the college dropout decision (2012). We see math misalignment as a form of early feedback that may affect students' academic progress in college and their STEM participation in particular. Therefore, STEM-aspiring students who experienced math misalignment and placed into lower levels of math may have lost the STEM momentum that they developed in high school.

Policy Implications

The STEM momentum framework also offers a way of thinking about policy changes that can sustain or increase STEM momentum. Since math misalignment was the consequence of placement testing and misaligned readiness standards, reforming and/or improving these may bolster the curricular domain of STEM momentum and mitigate any negative effects for the motivational domain of STEM momentum.

Several states across the nation have enacted legislation that emphasizes the use of multiple measures such as high school grades, a paradigm shift from the test-based placement scheme (Ross 2014). The shift towards using multiple measures means that community colleges must now place students using measures like high school GPA (HS GPA) and prior coursework instead of relying on placement test scores (Burks 2017). Indeed, California is one of the states that has refocused its assessment and placement policy from placement tests to multiple measures, with state-wide implementation in fall 2019 (Rodriguez et al. 2018). With respect to this shift, the present study concludes that aligning academic readiness standards by incorporating high school benchmarks may help reduce math misalignment and increase STEM participation in community colleges.

Specifically, the results suggest that if math misalignment were reduced, then students entering community colleges with STEM aspirations would likely complete more transferable STEM courses, and presumably, increase their likelihood of STEM degree attainment. One way to do so may be to remove placement testing requirements and make developmental education optional, as in the case of Florida (Hu et al. 2015). Students may then be more likely to enroll in transfer-level courses that are required for STEM pathways, and courses that maintain STEM momentum built in high school. That said, reforms that allow students to choose their own courses may have equity tradeoffs, as female students and students of color may be more likely to self-select or be counseled into lower-level math courses (Kosiewicz and Ngo 2019). This may therefore exacerbate misalignment rather than reduce it for some students.

Perhaps the most surefire way to reduce misalignment is to actively encourage inter-sector alignment between high schools and community colleges (Melguizo and Ngo 2020). Beyond incorporating high school information into the course placement and choice process, increased collaboration between high schools and community colleges can create a more seamless transition between sectors. For example, the California State Universities started to form partnerships with local high schools and to incentivize students to take math courses during the summer before their freshmen year as a way to prepare students for college-level coursework (Kurlaender et al. 2017). Similarly, community colleges may want to include local feeder high schools in the process of revamping their math sequence and their assessment and placement process. For one, colleges can partner with local high schools to inform students about how their high school records will affect their college trajectory. Increased inter-sector curricular alignment may help remove any unnecessary counter-momentum friction in the transition from high school to college.

Future Research

Our study provides directions for future research. First, this study focused on only one aspect of STEM momentum: curriculum and sequence progression. However, there are additional facets that make-up students' STEM momentum including, but not limited to, aspirations, motivations, beliefs, pedagogy, and teaching (Wang 2013a, 2017). When we describe math misalignment as an experience, we surmise that students may have received a discouraging signal of their math abilities from misaligned math placement. However, the math misalignment experience may be part of a suite of math experiences both within and outside of the math classroom. For instance, it may be that students who placed in lower-level math may also have experienced more skill-and-drill math instructional approaches than students in upper-level math (Cox 2015; Grubb and Gabriner 2013). Recent studies suggest the importance of active learning in boosting students' STEM persistence in community college (Wang et al. 2017). While we identify math misalignment as an important structural experience, we are unable to link math misalignment to teaching and learning that occurs inside the classroom and is an important caveat to our description of students' math misalignment experiences. A study with a focus on whether and how math misalignment alters students' aspirations as well as a look inside developmental math classroom pedagogical practices would complement the findings of this study.

In addition, this study also suggests an equity concern given that the majority of the students in this study are underrepresented racial minorities (URMs).[7] Over 75% of the students in our sample are URMs, many of whom are STEM-aspiring. However, many of these students were placed in remediation despite taking advanced math in high school and thus experienced math misalignment. This finding corresponds to studies that found URMs have a higher likelihood of experiencing conflicting math expectations in high school and in college (Fong and Melguizo 2017; Klasik and Strayhorn 2018; Rodriguez 2018). As increasing the number of URMs who enter STEM fields is a national imperative (National Science Board 2015), our findings suggest that the over-reliance on the placement test may have especially hindered STEM-aspiring URMs from pursuing STEM pathways. Future studies should examine racial and gender gaps in STEM achievement and explore ways to reduce STEM inequities in community college.

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Appendix

See Tables 6, 7, 8, 9, 10, 11, 12, 13 and 14.

[7] The racial-ethnic composition of underrepresented minorities in this study are Black, Hispanic, and Native American students as identifiable in the current data. Bahr et al.'s 2017 study on the STEM pathways in California Community Colleges also defined underrepresented minorities as Blacks, Hispanics, and Native Americans. Like the U.S. Census' definition of Hispanics, we define Hispanics as "a person of Cuban, Mexican, Puerto Rican, South or Central American or other Spanish culture or origin regardless of race." It is also important to note that Asian is a broad categorization that encompasses many different ethnicities, including Asian groups that are also underrepresented in STEM. However, the current data do not allow for disaggregating Asians.

Table 6 Crosswalk of major name, Classification of Instructional Program (CIP) code, and the Taxonomy of Program (TOP) code by STEM majors (life science and physical science/engineering)

Life science			Physical science/engineering		
Major	2-digit CIP Code	3- or 4-digit TOP Code	Major	2-digit CIP Code	3- or 4-digit TOP Code
Agricultural Sciences	01	101, 102	Computer and Information Sciences	11	116, 119, 614, In between 701–799
Natural Sciences and Conservation	03	114, 115, 301, 302, 399	Engineering	14	901, 934
Biological and Biomedical Sciences	26	401, 402, 403, 407, 410	[a]Engineering Technologies, Technicians	15	924, 934, 935, 943, 946, 953, 956, 957, 961, 999
Medical Assistant[b]	51	120, 121, 122, 123, 124, 125, 126, 129, 136, 1201, 1251, 1260, 1261	Mathematics and Statistics	27	1701, 1799
			Physical Science	40	1901, 1919, 1930, 1999
			Science Technologies, Technicians[a]	41	1920
			Mechanic, Repair Technologies, Technicians[a]	47	943, 953, 947, 948, 949, 950, 962,
			Biological and Physical Science and Mathematics	30	4902, 990

This categorization borrows from Wang's categorization in the 2016 study titled "*Course-taking patterns of community college students beginning in STEM: Using data mining techniques to reveal viable STEM transfer pathways*." The major, Biological and Physical Science and Mathematics, is included in this study but was not included in Wang's 2016 study

[a]This indicates that the majors is flagged as "likely terminal" meaning students who pursue these majors do not usually transfer to a 4-year university

[b]This is to note that the major was not included in Wang's study but is included in this study as medical assistants take a significant number of STEM courses

Table 7 Overlapping sample by GPA criteria

	HS GPA $\geq$ 3.0					
	Placed in transfer-level math	Misaligned one level below/placed in IA	Misaligned two levels below/placed in EA	Misaligned three levels below/placed in Pre-alg. & below	Under 3.0 GPA	N
Highest HS Math = Algebra 2						
Placed in transfer-level math	40%	0%	0%	0%	60%	432
Misaligned one level below/placed in IA	0%	21%	0%	0%	79%	3900
Misaligned two levels below/placed in EA	0%	0%	14%	0%	86%	5080
Misaligned three levels below/placed in Pre-alg. & below	0%	0%	0%	11%	90%	8764
Highest HS Math = Pre-Calculus						
Placed in transfer-level math	54%	0%	0%	0%	46%	1172
Misaligned one level below/placed in IA	0%	39%	0%	0%	61%	2826
Misaligned two levels below/placed in EA	0%	0%	31%	0%	69%	1782
Misaligned three levels below/placed in Pre-alg. & below	0%	0%	0%	26%	74%	2315
Highest HS Math = Calculus						
Placed in transfer-level math	72%	0%	0%	0%	28%	667
Misaligned one level below/placed in IA	0%	57%	0%	0%	43%	470
Misaligned two levels below/placed in EA	0%	0%	55%	0%	45%	122
Misaligned three levels below/placed in Pre-alg. & below	0%	0%	0%	61%	39%	170

Table 7 (continued)

	HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus					
	Placed in transfer-level math	Misaligned one level below/placed in IA	Misaligned two levels below/placed in EA	Misaligned three levels below/placed in Pre-alg. & below	Under 3.4 GPA	N
Highest HS Math = Algebra 2						
Placed in transfer-level math	19%	0%	0%	0%	82%	432
Misaligned one level below/placed in IA	0%	5%	0%	0%	95%	3900
Misaligned two levels below/placed in EA	0%	0%	3%	0%	97%	5080
Misaligned three levels below/placed in Pre-alg. & below	0%	0%	0%	2%	98%	8764
Highest HS Math = Pre-Calculus						
Placed in transfer-level math	22%	0%	0%	0%	78%	1172
Misaligned one level below/placed in IA	0%	14%	0%	0%	87%	2826
Misaligned two levels below/placed in EA	0%	0%	8%	0%	92%	1782
Misaligned three levels below/placed in Pre-alg. & below	0%	0%	0%	7%	93%	2315
Highest HS Math = Calculus						
Placed in transfer-level math	90%	0%	0%	0%	10%	667
Misaligned one level below/placed in IA	0%	83%	0%	0%	17%	470
Misaligned two levels below/placed in EA	0%	0%	80%	0%	21%	122
Misaligned three levels below/placed in Pre-alg. & below	0%	0%	0%	87%	13%	170

The percentages add up to 100% (row percentages)

IA intermediate algebra, *EA* elementary algebra

Table 8 Description of missing values

Variable	Missing	Rationale	Solution
Female	0	N/A	N/A
Asian	0	N/A	N/A
Black	0	N/A	N/A
Hispanic	0	N/A	N/A
White	0	N/A	N/A
Other	0	N/A	N/A
Special education	0	N/A	N/A
English learner categorization	44	Will assume random missing	Dummy code
Honors or AP	68	Will assume random missing	Dummy code
Years of A-G Math	0	N/A	N/A
Years of A-G Science	0	N/A	N/A
11th Grade Math CST score	20,355	For grades 8–11, the test depends upon the particular math course in which the student is enrolled. Grades 9–11 took summative math CST; Include a control variable for the math course taken in 11th grade	Dummy code
11th Grade Science CST score	19,236	The science test depends on the course in which students are enrolled; Include a control variable for the science course taken in 11th grade	Dummy code
Cumulative HS GPA	56	Will assume random missing	Dummy code; 8 cases replaced with the mean
Number of non-AP advanced math	0	N/A	N/A
Number of AP math or science	0	N/A	N/A

Table 9 High school-by-college fixed effects estimation of math misalignment using last high school math course

	(1) Last HS Math = Algebra 2	(2) Last HS Math = Pre-Calculus	(3) Last HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Transferable math units, 2 Years					
Misaligned one level below/placed in IA	− 1.92***	− 2.00***	− 2.67***	− 2.34***	− 2.43***
	(0.15)	(0.22)	(0.40)	(0.19)	(0.27)
Misaligned two levels below/placed in EA	− 2.16***	− 2.48***	− 3.62***	− 2.78***	− 3.29***
	(0.15)	(0.22)	(0.67)	(0.21)	(0.32)
Misaligned three levels below/placed in Pre-alg. & below	− 2.29***	− 2.56***	− 2.60**	− 3.06***	− 3.20***
	(0.15)	(0.23)	(0.84)	(0.23)	(0.38)
Transferable STEM units, 2 Years					
Misaligned one level below/placed in IA	− 2.57***	− 3.21***	− 3.82***	− 3.79***	− 3.18***
	(0.40)	(0.47)	(0.86)	(0.44)	(0.57)
Misaligned two levels below/placed in EA	− 3.14***	− 4.00***	− 5.59***	− 4.84***	− 5.17***
	(0.43)	(0.48)	(1.24)	(0.48)	(0.63)
Misaligned three levels below/placed in Pre-alg. & below	− 3.57***	− 4.27***	− 3.81*	− 5.33***	− 5.21***
	(0.43)	(0.49)	(1.71)	(0.55)	(0.91)
Transferable stem units completed					
Misaligned one level below/placed in IA	− 3.90***	− 3.94***	− 6.42***	− 4.70***	− 4.33***
	(0.89)	(0.68)	(1.71)	(0.75)	(1.10)
Misaligned two levels below/placed in EA	− 5.15***	− 5.74***	− 10.23***	− 6.77***	− 8.86***
	(0.94)	(0.69)	(1.83)	(0.74)	(1.13)
Misaligned three levels below/placed in Pre-alg. & below	− 5.90***	− 6.06***	− 11.05***	− 7.96***	− 9.45***
	(0.92)	(0.73)	(2.64)	(0.82)	(1.34)

Table 9 continued

	(1) Last HS Math = Algebra 2	(2) Last HS Math = Pre-Calculus	(3) Last HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Number of high school by college clusters	616	423	202	420	282
Number of students	16,564	8091	1339	7321	2997

All estimation includes the following covariates: gender, race, whether or not the student lives within the school district, students' primary language, whether or not the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associates degree, whether students took AP or honors courses in high school, HS GPA (except when HS GPA is the math misalignment criteria), 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

IA intermediate algebra, *EA* elementary algebra

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10 Interaction estimation of math misalignment using last high school math course and STEM aspiration on STEM outcomes

	(1) Last HS Math = Algebra 2	(2) Last HS Math = Pre-Calculus	(3) Last HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Transferable math units completed, 2 Years					
STEM-aspiring	1.57**	1.47***	2.04***	2.05***	2.63***
	(0.51)	(0.37)	(0.58)	(0.36)	(0.42)
Misaligned one level below	− 1.61***	− 1.68***	− 2.46***	− 1.82***	− 1.80***
	(0.16)	(0.21)	(0.43)	(0.20)	(0.29)
Misaligned two levels below	− 1.80***	− 2.10***	− 3.33***	− 2.22***	− 2.59***
	(0.16)	(0.22)	(0.76)	(0.24)	(0.36)
Misaligned three levels below	− 1.92***	− 2.19***	− 2.32**	− 2.53***	− 2.50***
	(0.17)	(0.24)	(0.76)	(0.25)	(0.39)
Misaligned one level below X STEM-aspiring	− 1.14*	− 0.88*	− 0.14	− 1.48***	− 1.45**
	(0.54)	(0.41)	(0.83)	(0.39)	(0.55)
Misaligned two levels below X STEM-aspiring	− 1.39**	− 1.07**	− 0.27	− 1.69***	− 1.75**
	(0.50)	(0.37)	(1.41)	(0.42)	(0.55)
Misaligned three levels below X STEM-aspiring	− 1.48**	− 1.02*	0.10	− 1.54***	− 1.78**
	(0.51)	(0.40)	(1.14)	(0.39)	(0.54)
Transferable STEM units completed, 2 Years					
STEM-aspiring	3.33***	4.78***	6.12***	6.16***	7.12***
	(0.93)	(0.78)	(1.01)	(0.63)	(0.75)
Misaligned one level below	− 2.30***	− 2.52***	− 3.48***	− 2.62***	− 1.95**
	(0.49)	(0.40)	(0.83)	(0.45)	(0.60)
Misaligned two levels below	− 2.69***	− 3.11***	− 4.26**	− 3.49***	− 3.72***
	(0.52)	(0.46)	(1.37)	(0.56)	(0.71)
Misaligned three levels below	− 2.92***	− 3.28***	− 3.48*	− 3.98***	− 3.97***
	(0.52)	(0.48)	(1.62)	(0.58)	(0.89)

Table 10 (continued)

	(1) Last HS Math = Algebra 2	(2) Last HS Math = Pre-Calculus	(3) Last HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Misaligned one level below X STEM-aspiring	−0.59	−1.50	0.47	−2.97***	−2.43*
	(1.01)	(0.88)	(1.89)	(0.76)	(1.08)
Misaligned two levels below X STEM-aspiring	−1.37	−2.19*	−2.58	−3.83***	−3.13*
	(0.94)	(0.85)	(2.38)	(0.80)	(1.24)
Misaligned three levels below X STEM-aspiring	−2.45**	−2.61**	1.93	−3.75***	−2.38*
	(0.94)	(0.91)	(2.14)	(0.70)	(1.02)
Transferable STEM units completed					
STEM-aspiring	9.77***	11.36***	13.52***	14.32***	14.95***
	(1.95)	(1.10)	(1.82)	(1.04)	(1.22)
Misaligned one level below	−2.75***	−2.20***	−5.11**	−2.33***	−2.09
	(0.81)	(0.63)	(1.66)	(0.65)	(1.11)
Misaligned two levels below	−3.60***	−3.74***	−7.42***	−3.85***	−6.21***
	(0.82)	(0.70)	(1.92)	(0.73)	(1.15)
Misaligned three levels below	−4.07***	−3.94***	−8.88***	−5.16***	−6.97***
	(0.82)	(0.76)	(2.63)	(0.76)	(1.33)
Misaligned one level below X STEM-aspiring	−3.42	−4.05**	−0.74	−5.63***	−4.04*
	(2.00)	(1.25)	(3.32)	(1.14)	(1.65)
Misaligned two levels below X STEM-aspiring	−5.25**	−4.67***	−4.95	−8.14***	−4.99
	(1.89)	(1.28)	(3.08)	(1.46)	(2.55)
Misaligned three levels below X STEM-aspiring	−6.63**	−5.11***	−0.73	−7.33***	−4.70**
	(2.02)	(1.41)	(2.93)	(1.27)	(1.65)

Table 10 (continued)

	(1) Last HS Math = Algebra 2	(2) Last HS Math = Pre-Calculus	(3) Last HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Number of high school by college clusters	616	423	202	420	282
Number of students	16,564	8091	1339	7321	2997

STEM-aspiring is a dichotomous variable indicating students who intend to pursue a STEM major in their college application. The outcome is observed within 2 years of first enrollment in community college. All estimation includes the following covariates: gender, race, whether or not the student lives within the school district, students' primary language, whether or not the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associates degree, whether students took AP or honors courses in high school, HS GPA (except when HS GPA is the math misalignment criteria), 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11 High school-by-college fixed effects estimation of math misalignment using math enrollment

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Panel A. Passing math requirement for AA					
Misaligned one level below/placed in IA	−1.52***	−2.10***	−2.09***	−2.69***	−2.75***
	(0.16)	(0.23)	(0.48)	(0.23)	(0.31)
Misaligned two levels below/placed in EA	−1.98***	−2.65***	−3.06***	−3.18***	−3.54***
	(0.17)	(0.21)	(0.63)	(0.20)	(0.29)
Misaligned three levels below/placed in Pre-alg. & below	−2.17***	−2.99***	−4.35***	−3.70***	−4.22***
	(0.17)	(0.20)	(0.45)	(0.20)	(0.30)
Panel B. Transferable STEM units attempted					
Misaligned one level below/placed in IA	−2.40***	−3.43***	−2.68*	−4.45***	−3.83***
	(0.33)	(0.51)	(1.05)	(0.47)	(0.65)
Misaligned two levels below/placed in EA	−3.27***	−4.39***	−4.57***	−5.37***	−5.30***
	(0.35)	(0.47)	(1.24)	(0.45)	(0.62)
Misaligned three levels below/placed in Pre-alg. & below	−4.37***	−5.75***	−8.38***	−7.06***	−7.76***
	(0.36)	(0.48)	(1.00)	(0.49)	(0.72)
Panel C. Transferable STEM units completed					
Misaligned one level below/placed in IA	−2.75***	−4.47***	−3.66	−5.97***	−4.78***
	(0.66)	(0.71)	(1.91)	(0.71)	(1.11)
Misaligned two levels below/placed in EA	−4.42***	−6.39***	−8.42***	−7.96***	−9.04***
	(0.72)	(0.67)	(1.80)	(0.67)	(1.10)
Misaligned three levels below/placed in Pre-alg. & Below	−6.80***	−9.86***	−16.39***	−12.50***	−14.92***
	(0.71)	(0.67)	(1.44)	(0.63)	(1.01)

Table 11 continued

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Number of high school by college clusters	648	426	207	420	286
Number of students	18,176	8095	1429	7321	3046

All estimation includes the following covariates: gender, race, whether or not the student lives within the school district, students' primary language, whether or not the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associates degree, whether students took AP or honors courses in high school, HS GPA (except when HS GPA is the math misalignment criteria), 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

IA intermediate algebra, *EA* elementary algebra

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12 Interaction estimation of math misalignment using math enrollment and STEM aspiration on STEM outcomes

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Transferable math units completed, 2 Years					
STEM-aspiring	1.45**	1.34***	1.97**	1.81***	2.55***
	(0.46)	(0.37)	(0.63)	(0.39)	(0.46)
Misaligned one level below	−1.22***	−1.85***	−2.14***	−2.21***	−2.07***
	(0.19)	(0.22)	(0.52)	(0.25)	(0.33)
Misaligned two levels below	−1.64***	−2.35***	−2.77***	−2.72***	−2.97***
	(0.21)	(0.21)	(0.74)	(0.25)	(0.35)
Misaligned three levels below	−1.82***	−2.58***	−3.96***	−3.16***	−3.43***
	(0.21)	(0.19)	(0.58)	(0.24)	(0.36)
Misaligned one level below X STEM-aspiring	−1.14*	−0.64	0.30	−1.30**	−1.53*
	(0.48)	(0.41)	(1.03)	(0.42)	(0.61)
Misaligned two levels below X STEM-aspiring	−1.28**	−0.80*	−0.50	−1.27**	−1.30*
	(0.47)	(0.36)	(1.14)	(0.45)	(0.63)
Misaligned three levels below X STEM-aspiring	−1.33**	−1.24***	−0.31	−1.41***	−1.76**
	(0.47)	(0.37)	(1.04)	(0.42)	(0.66)
Transferable STEM units completed, 2 Years					
STEM-aspiring	3.68***	4.38***	5.94***	5.59***	6.77***
	(0.99)	(0.84)	(1.11)	(0.78)	(0.83)
Misaligned one level below	−1.93***	−2.91***	−3.08**	−3.36***	−2.59***
	(0.40)	(0.43)	(1.07)	(0.55)	(0.67)
Misaligned two levels below	−2.75***	−3.75***	−3.76**	−4.26***	−4.47***
	(0.42)	(0.43)	(1.37)	(0.57)	(0.66)
Misaligned three levels below	−3.61***	−4.69***	−7.87***	−5.71***	−6.32***
	(0.43)	(0.43)	(1.14)	(0.58)	(0.75)

Table 12 (continued)

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Misaligned one level below X STEM-aspiring	− 1.58	− 1.10	1.40	− 2.62**	− 2.57*
	(1.07)	(0.92)	(2.33)	(0.87)	(1.17)
Misaligned two levels below X STEM-aspiring	− 1.77	− 1.48	− 1.49	− 2.92**	− 1.53
	(1.02)	(0.83)	(2.07)	(0.95)	(1.18)
Misaligned three levels below X STEM-aspiring	− 2.68**	− 2.68**	1.50	− 3.14***	− 2.07
	(1.00)	(0.85)	(2.70)	(0.94)	(1.58)
Transferable STEM units completed					
STEM-aspiring	9.29***	11.26***	12.07***	13.61***	13.87***
	(1.76)	(1.11)	(1.74)	(1.21)	(1.40)
Misaligned one level below	− 1.55**	− 2.78***	− 3.86*	− 3.57***	− 2.86*
	(0.54)	(0.67)	(1.91)	(0.72)	(1.11)
Misaligned two levels below	− 3.12***	− 4.76***	− 7.54***	− 5.68***	− 7.66***
	(0.53)	(0.67)	(1.87)	(0.63)	(0.99)
Misaligned three levels below	− 4.94***	− 7.16***	− 14.50***	− 9.21***	− 12.07***
	(0.52)	(0.64)	(1.33)	(0.63)	(0.84)
Misaligned one level below X STEM-aspiring	− 4.01*	− 4.08***	1.40	− 5.48***	− 3.39
	(1.67)	(1.21)	(3.37)	(1.38)	(1.91)
Misaligned two levels below X STEM-aspiring	− 4.35*	− 3.72**	− 0.73	− 5.68***	− 2.30
	(1.80)	(1.32)	(2.71)	(1.43)	(2.09)
Misaligned three levels below X STEM-aspiring	− 6.41***	− 6.75***	− 0.24	− 7.86***	− 4.02
	(1.81)	(1.22)	(4.30)	(1.48)	(2.33)

Table 12 (continued)

	(1) Highest HS Math = Algebra 2	(2) Highest HS Math = Pre-Calculus	(3) Highest HS Math = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Number of high school by college clusters	648	426	207	420	286
Number of students	18,176	8095	1429	7321	3046

STEM-aspiring is a dichotomous variable indicating students who intend to pursue a STEM major in their college application. The outcome is observed within 2 years of first enrollment in community college. All estimation includes the following covariates: gender, race, whether or not the student lives within the school district, students' primary language, whether or not the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associates degree, whether students took AP or honors courses in high school, HS GPA (except when HS GPA is the math misalignment criteria), 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13 High school-by-college fixed effects estimation of math misalignment using highest high school math course passed with A or B

	(1) Highest HS Math A/B = Algebra 2	(2) Highest HS Math A/B = Pre-Calculus	(3) Highest HS Math A/B = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Passing math requirement for AA					
Misaligned one level below/placed in IA	− 1.71***	− 2.54***	− 1.80**	− 2.34***	− 2.26***
	(0.17)	(0.32)	(0.62)	(0.19)	(0.32)
Misaligned two levels below/placed in EA	− 2.01***	− 3.30***	− 3.05**	− 2.78***	− 3.20***
	(0.17)	(0.32)	(1.15)	(0.21)	(0.33)
Misaligned three levels below/placed in Pre-alg. & below	− 2.20***	− 3.08***	− 2.28	− 3.06***	− 3.36***
	(0.19)	(0.34)	(1.44)	(0.23)	(0.41)
Transferable STEM units attempted					
Misaligned one level below/placed in IA	− 2.93***	− 3.63***	− 2.46	− 3.79***	− 2.96***
	(0.37)	(0.66)	(1.53)	(0.44)	(0.75)
Misaligned two levels below/placed in EA	− 3.57***	− 5.01***	− 5.00*	− 4.84***	− 5.35***
	(0.43)	(0.63)	(2.50)	(0.48)	(0.76)
Misaligned three levels below/placed in Pre-alg. & below	− 3.96***	− 4.48***	− 4.09	− 5.33***	− 5.77***
	(0.45)	(0.70)	(3.11)	(0.55)	(1.06)
Transferable STEM units completed					
Misaligned one level below/placed in IA	− 4.21***	− 4.86***	− 6.77*	− 4.70***	− 4.42***
	(0.75)	(0.94)	(2.68)	(0.75)	(1.28)
Misaligned two levels below/placed in EA	− 5.63***	− 7.96***	− 10.53***	− 6.77***	− 9.21***
	(0.78)	(0.97)	(2.86)	(0.74)	(1.26)
Misaligned three levels below/placed in Pre-alg. & below	− 6.06***	− 7.62***	− 11.81**	− 7.96***	− 9.97***
	(0.79)	(1.07)	(4.35)	(0.82)	(1.60)

Table 13 (continued)

	(1) Highest HS Math A/B = Algebra 2	(2) Highest HS Math A/B = Pre-Calculus	(3) Highest HS Math A/B = Calculus	(4) HS GPA $\geq$ 3.0	(5) HS GPA $\geq$ 3.4 OR HS GPA $\geq$ 2.6 and took calculus
Number of high school by college clusters	480	330	143	413	265
Number of students	8975	4040	666	7116	2508

All estimation includes the following covariates: gender, race, whether or not the student lives within the school district, students' primary language, whether or not the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associates degree, whether students took AP or honors courses in high school, HS GPA (except when HS GPA is the math misalignment criteria), 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

IA intermediate algebra, *EA* elementary algebra

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 14 Interaction estimation of math misalignment using highest high school math passed with A or B and STEM aspiration on STEM outcomes

	(1) Highest HS Math A/B = Algebra 2	(2) Highest HS Math A/B = Pre-Calculus	(3) Highest HS Math A/B = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Passing math requirement for AA					
STEM-aspiring	1.56***	2.11***	1.62*	2.05***	2.47***
	(0.44)	(0.48)	(0.82)	(0.36)	(0.47)
Misaligned one level below	− 1.37***	− 2.10***	− 1.54*	− 1.82***	− 1.64***
	(0.19)	(0.32)	(0.74)	(0.20)	(0.32)
Misaligned two levels below	− 1.62***	− 2.71***	− 3.29**	− 2.22***	− 2.58***
	(0.21)	(0.34)	(1.17)	(0.24)	(0.35)
Misaligned three levels below	− 1.78***	− 2.64***	− 1.62	− 2.53***	− 2.62***
	(0.22)	(0.34)	(1.48)	(0.25)	(0.40)
Misaligned one level below X STEM-aspiring	− 1.02*	− 1.12*	− 0.31	− 1.48***	− 1.42*
	(0.45)	(0.56)	(1.23)	(0.39)	(0.67)
Misaligned two levels below X STEM-aspiring	− 1.25**	− 1.63**	1.06	− 1.69***	− 1.45*
	(0.39)	(0.51)	(2.31)	(0.42)	(0.59)
Misaligned three levels below X STEM-aspiring	− 1.38**	− 1.08	− 1.98	− 1.54***	− 2.07***
	(0.44)	(0.62)	(1.43)	(0.39)	(0.55)
Transferable STEM units attempted					
STEM-aspiring	4.53***	6.26***	5.62***	6.16***	7.04***
	(0.74)	(1.03)	(1.51)	(0.63)	(0.86)
Misaligned one level below	− 2.31***	− 2.65***	− 2.13	− 2.62***	− 1.69*
	(0.50)	(0.69)	(1.54)	(0.45)	(0.71)
Misaligned two levels below	− 2.77***	− 3.59***	− 4.71	− 3.49***	− 3.94***
	(0.56)	(0.71)	(2.48)	(0.56)	(0.79)
Misaligned three levels below	− 2.96***	− 3.24***	− 3.24	− 3.98***	− 4.44***
	(0.56)	(0.76)	(3.14)	(0.58)	(1.01)

Table 14 (continued)

	(1) Highest HS Math A/B = Algebra 2	(2) Highest HS Math A/B = Pre-Calculus	(3) Highest HS Math A/B = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Misaligned one level below X STEM-aspiring	− 1.42	− 2.24	0.92	− 2.97***	− 2.44
	(0.85)	(1.26)	(3.10)	(0.76)	(1.29)
Misaligned two levels below X STEM-aspiring	− 2.20**	− 3.55**	− 0.04	− 3.83***	− 2.84*
	(0.84)	(1.15)	(4.37)	(0.80)	(1.29)
Misaligned three levels below X STEM-aspiring	− 3.18***	− 3.02*	− 0.03	− 3.75***	− 2.64*
	(0.76)	(1.19)	(2.70)	(0.70)	(1.19)
Transferable STEM units completed					
STEM-aspiring	11.51***	13.00***	11.54***	14.32***	14.86***
	(1.48)	(1.52)	(3.22)	(1.04)	(1.49)
Misaligned one level below	− 2.54***	− 2.68**	− 5.34*	− 2.33***	− 2.17
	(0.69)	(0.86)	(2.46)	(0.65)	(1.28)
Misaligned two levels below	− 3.49***	− 5.17***	− 9.98**	− 3.85***	− 6.64***
	(0.72)	(1.01)	(3.50)	(0.73)	(1.26)
Misaligned three levels below	− 3.65***	− 5.54***	− 9.28*	− 5.16***	− 7.28***
	(0.74)	(1.12)	(4.33)	(0.76)	(1.55)
Misaligned one level below X STEM-aspiring	− 3.96*	− 5.20**	− 0.41	− 5.63***	− 3.73
	(1.67)	(1.77)	(5.90)	(1.14)	(1.92)
Misaligned two levels below X STEM-aspiring	− 6.00***	− 6.58***	0.25	− 8.14***	− 4.34
	(1.54)	(1.74)	(5.50)	(1.46)	(2.84)
Misaligned three levels below X STEM-aspiring	− 7.32***	− 4.10*	− 3.76	− 7.33***	− 5.28*
	(1.51)	(2.01)	(5.02)	(1.27)	(2.10)

Table 14 (continued)

	(1) Highest HS Math A/B = Algebra 2	(2) Highest HS Math A/B = Pre-Calculus	(3) Highest HS Math A/B = Calculus	(4) HS GPA ≥ 3.0	(5) HS GPA ≥ 3.4 OR HS GPA ≥ 2.6 and took calculus
Number of high school by college clusters	480	330	143	413	265
Number of students	8975	4040	666	7116	2508

STEM-aspiring is a dichotomous variable indicating students who intend to pursue a STEM major in their college application. The outcome is observed within 2 years of first enrollment in community college. All estimation includes the following covariates: gender, race, whether or not the student lives within the school district, students' primary language, whether or not the student is a U.S. citizen, ELL status, SPED status, transfer intent or intent to pursue an Associates degree, whether students took AP or honors courses in high school, HS GPA (except when HS GPA is the math misalignment criteria), 11th grade math and science CST scores, the different types of 11th grade math and science course students took, years of math and science A-G courses taken, whether students took at advanced math (geometry or above) in high school, the number of AP math or science courses taken, high school-by-college and year fixed effects. Standard errors are clustered at the high school-by-college level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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