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Are Homeschoolers Prepared for College Calculus?

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Homeschooling in the United States has grown considerably over the past several decades. This article presents findings from the Factors Influencing College Success in Mathematics (FICSMath) survey, a national study of 10,492 students enrolled in tertiary calculus, including 190 students who reported homeschooling for a majority of their high school years. The authors found that, compared with students who received other types of secondary schooling, students who homeschooled: (a) were demographically similar to their peers, (b) earned similar SAT Math scores, and (c) earned higher tertiary calculus grades.

KEYWORDS *school choice, homeschool, mathematics, calculus, FICSMath*

The education of students who homeschool has attracted growing interest over the past decade, not least because the number of such students appears to have reached considerable proportions. While we lack current data (and, for that matter, cannot conduct an accurate headcount) because many states and localities do not require families to report homeschooling (HSLDA, 2014), the National Center for Education Statistics (NCES, 2007), in 2007, estimated the number of students who homeschooled at about 1.5 million students, or 2.9% of the school-age population (Bielick, 2008; estimates

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were generated using National Household Education Survey [NHES] sample data). Since that time, the current population of homeschooled students is thought to have increased to over 2 million students (as of 2013–2014), or more than 4% of the school-age population (Basham, Merrifield, & Hepburn, 2007; Boschee & Boschee, 2011; Kunzman & Gaither, 2013). Homeschooling, therefore, involves a larger number of students than do charter schools, which have attracted far more public interest and a larger share of systematic scholarly attention (NCES, 2013a; nationwide charter school enrollment of ~1.8 million students [2010–2011]; Kafer, 2009).

With the growing proportion of newly graduated homeschooled students knocking on the door of admission to colleges and universities across the United States, there has been particular interest among scholars on the academic performance of students who homeschool (Gloeckner & Jones, 2013). Specifically, scholars have focused on the extent to which homeschooling "works," for whom, and under what conditions. Belfield (2005) characterized the overarching research interests of the field as including both "the absolute performance of homeschoolers [and] the treatment effect of homeschooling" (p. 170). To date, we know surprisingly little about either domain. Work on the performance of homeschoolers—to which this article seeks to contribute—has remained largely anecdotal, subject to bias, and highly politicized (including experimental or quasi-experimental work; for a good review of approaches and examples, see Murnane & Willett, 2011). A survey of literature revealed mixed findings when college level grade point average was compared between traditionally prepared students and homeschooled students (Gloeckner & Jones, 2013). Little work has been capable of shedding light on the treatment effect of homeschooling (including experimental or quasi-experimental work; for a good review of approaches and examples, see Murnane & Willett, 2011).

CHALLENGES OF HOMESCHOOL RESEARCH

Why is our knowledge base so thin? A persistent challenge of studying homeschooling has been that students who homeschool do so beyond the institutional structures of traditional schools, and across widely varying political landscapes. The business of assembling representative datasets capable of accurately characterizing the experiences and performance of homeschooled students has historically proven to be close to impossible (Kunzman & Gaither, 2013). We have, therefore, been forced to make estimates about homeschoolers from small samples. The most recent 2007 National Household Education Survey (National Center for Education Statistics, 2009), and perhaps the most credible portrait of homeschooling nationwide, estimated characteristics of the national homeschooling population from a sample of 290 students.

A second factor complicating any homeschool research has been defining the scope and scale of the treatment. Belfield (2005) and Jones-Sanpei (2008) both pointed out that homeschooling is often not an either–or proposition. While some families pursue comprehensive at-home approaches, many homeschooling students participate in school-based distance learning programs, or attend a local school for part of the day. The 2007 Parent and Family Involvement in Education survey (Herrold & O'Donnell, 2008) reported 16% of homeschoolers as "[e]nrolled in school part time." Moreover, it is a rare student who exclusively homeschools over the entire K–12 grade span. Though (again) data are thin, Isenberg (2002) estimated a mean homeschooling duration of just two years—and later noted high attrition (63%) after the first year of homeschooling (Isenberg, 2007). At the moment, we can make few claims about what homeschooling is, or what common experiences students who homeschool share.

A third and ongoing challenge is that research on homeschooling in the modern era has been intensely politicized. A great deal of the available scholarship has been conducted or published by advocacy organizations, or by scholars with explicit agendas to promote or criticize homeschooling (for a good review, see Gaither, 2008). Advocates have claimed that homeschooling promotes flexibility, individualization, and improved academic performance of students, including those with "special learning needs" (Ray, 2010; Rudner, 1999). Critics have worried about homeschooling's potential for unreported abuse, psychological harm, and uneven academic rigor (West, 2009). Contrast, for example, one recent claim made by Brian Ray (2009), a researcher sponsored by the advocacy group Home School Legal Defense Association (HSLDA): "Homeschoolers are still achieving well beyond their public school counterparts . . ." (p. 3) with a counterclaim by Robin West (2009) of the Georgetown University Law Center:

> There is indeed no credible evidence that homeschoolers as a group do worse on standardized tests, but contrary to their [i.e., the advocates'] claims, there is also no credible evidence that they do better. There is no credible evidence of accomplishment here at all. (p. 10)

Such work has generated considerable noise without consensus. As Kunzman and Gaither (2013) summarize: ". . . unfortunately most of this work contains serious design flaws that limit its generalizability and reliability" (p. 16).

HOMESCHOOLERS AND ACADEMIC PERFORMANCE

Two exceptions to this are studies by Belfield (2005), who found that homeschoolers taking the SAT scored slightly better than expected on the SAT verbal section, and slightly lower than expected on the SAT math section, and Qaqish (2007), who found that homeschoolers taking the ACT scored slightly lower than expected on the mathematics section. Belfield's data, which encompassed the 2001 cohort of SAT takers, contained 6,033 students identified as homeschoolers. They also included a range of self-reported demographic controls. Belfield's analysis clearly addressed the challenges presented by the self-selected cohort of students taking the SAT and attempted to correct for selection effects (e.g., relatively low proportions of homeschoolers take the SAT) and family background controls (e.g., homeschoolers were found to be advantaged, on average, in terms of family wealth and educational background). Belfield concluded, with a range of caveats, that the slightly higher SAT verbal scores he reported "may reflect greater parental competence" in reading/writing than in mathematics (p. 173). Qaqish's data included 1,477 homeschooled students and 1,477 nonhomeschoolers taking the ACT mathematics test prior to March 2003. Qaqish's design constructed matched groups of homeschoolers and nonhomeschoolers by gender, grade, race/ethnicity, and family income, and used these groups to calculate mean scores for each test item, along with total ACT mathematics raw scores—and found that mean scores for nonhomeschooled students were slightly higher than those of homeschooled students.

Belfield (2005) also explored the course taking and academic performance of homeschoolers as a group, and found that homeschoolers demonstrated divergent proficiency across content areas, in comparison with students who experienced a range of other types of schooling. Belfield's (2005) work is unique in that it avoided the use of a self-selected sample (e.g., of SAT- or ACT-takers), reported on the courses homeschoolers took while in high school and college, and did not rely on post hoc controls for selection bias or demography.

RESEARCH QUESTION

With the previous results representing the extent of our reliable information, there appears to be a dire need to augment and improve the knowledge base. Our study intends to make a contribution to knowledge about the preparation of homeschoolers for—and success in—tertiary calculus courses. In this research, tertiary calculus is referred to as the first single variable calculus course taken at the college level. We analyze data from the 2009–2010 Factors Influencing College Success in Mathematics (FICSMath) survey, a nationally representative study of 10,492 students who completed the FICSMath survey at the beginning of their tertiary calculus course. The group of 190 homeschool students in the FICSMath study affords the unique opportunity of gaining nationally representative insight into homeschooling. We address the following tripartite research question: Among college calculus students, to what extent do homeschoolers differ from their nonhomeschooled peers in (a) demographic and socioeconomic background characteristics, (b) secondary mathematics preparation, and (c) performance in tertiary calculus?

DATA AND METHODS

The FICSMath survey project, conducted at the Science Education Department of the Harvard-Smithsonian Center for Astrophysics, with funding from the National Science Foundation (NSF Award # 0813702) is among the few—and certainly the most recent—national-level studies of students' mathematics course taking, instructional experiences, and performance in tertiary calculus. The FICSMath research emerged from previous research—the Factors Influencing College Science Success (FICSS) study—that identified secondary mathematics as the only significant positive predictor of performance across all three freshman college science courses of biology, chemistry, and physics (Tai & Sadler, 2007). FICSMath institution recruitment, sample selection, item generation, pilot testing, and instrument validity and reliability are capably described elsewhere (Barnett, Sonnert, & Sadler, 2012; Wade, 2011).

The FICSMath dataset includes a large sample of college students who were enrolled in tertiary calculus at a broad range of institutions, from community colleges to Research I universities. A stratified random sample of the institutions of higher education contained in the National Center for Education Statistics (NCES) Integrated Postsecondary Education Data System as of 2007, was drawn: The institutions were first stratified by type (2-year versus 4-year), and each of the resulting two bins was then subdivided into three by size (small, medium, and large). Surveys were received from students in 134 participant institutions across the United States. Students took the FICSMath survey near the beginning of the 2009 Fall semester. Professors then held the surveys until after the completion of the course, at which time they recorded the students' grades earned in the course. The main dependent variable is student performance in tertiary calculus. In the end, there were 10,492 surveys returned to Harvard University, with no student identifiers.

For this article, we have tried not to rely heavily on student perception (e.g., whether they worked hard in high school), but only on relatively concrete aspects of tertiary calculus students' recalled experiences (such as course taking). The accuracy and reliability of self-report depends primarily on context, relevance, and survey clarity (Bradburn, 2000; Niemi & Smith, 2003; Pace, Barahona, & Kaplan, 1985). In particular, self-reports of course taking, grades earned, and standardized test scores made by college students tend to be highly accurate when compared to transcript records (Anaya, 1999; Baird, 1976). In a recent review of existing research on self-report, Kuncel, Credé, and Thomas (2005) concluded that self-report may be characterized as particularly accurate in samples where the surveys address issues relevant to the respondents. In this case, students completed the FICSMath survey in tertiary calculus during the beginning of their fall semester, which is when reflection upon students' prior experience is commonplace. To gauge reliability, we conducted a test–retest study in which 174 students from three different colleges took the survey twice, 2 weeks apart. Our analysis found that, for groups of 100, less than a 0.04% chance of reversal existed.

Our analysis excludes students who attended high schools outside of the United States (n = 838, or 8.0% of the dataset) and the small number of students who reported attending specialty "all-male" or "all-female" high schools, "vocational" high schools, "International Baccalaureate (IB)" schools, and "Magnet schools." These latter exclusions (n = 577 students in total, or 5.6% of the dataset) were made to avoid analytic uncertainty. The FICSMath survey question about high school type (Q2: What type of high school did you go to?) allowed students to select multiple options—confounding interpretation of responses from some students who selected more than one high school type. Students who reported attending both a "Public" school and a "Public Charter" school (n = 22) are similarly excluded from this analysis.

These exclusions, while a relatively small percentage of the dataset, present a risk of mischaracterizing students who attended Parochial schools, many of which are single-gender (Spielhagen, using 2011–2012 National Catholic Education Association data, reported that 31.5% of Catholic high schools were single gender [2013, p. 69]). These exclusions also present a risk of mischaracterizing students who attended private, non-Parochial or charter schools, an unknown percentage of which are single gender. Readers are cautioned that our reporting on "private, Parochial," "private non-Parochial," and "charter" schools, while of policy interest to many (and therefore included despite such cautions), does not include students who attended single-gender, vocational, magnet, or IB variants.

RESULTS

The vast majority of students who completed the FICSMath survey attended public high schools (n = 7,803, or 86.0%), while a relatively small percent of respondents reported homeschooling for a majority of high school (n = 190, or 2.1%). This percentage appears similar to the (2007) NCES estimate of 2.9% of the school-aged population, and somewhat smaller than Ray's (2011) estimate of 3.5%–4.7% (although Ray's methodology and advocacy leave us more comfortable relying on the NCES study, despite its age). That the sample of students who homeschooled in the FICSMath dataset appears quite similar to a national estimate of the percentage homeschooling during the K–12 school years is, we think, a strong argument against the existence of any extreme selection bias. Not all students who graduated from high school (homeschooled or otherwise) attended college in 2010, and neither did all homeschooled students who attended college in 2010 take the FICSMath survey. We believe the 2.1% homeschooling rate to be a representative sample of the population, which will contribute to the importance of the findings we describe as follows. Additionally, the FICSMath data set of homeschoolers includes variables unavailable through the 2007 National Household Education Survey, which made national-level estimates from a sample size of 290 homeschoolers. Using the somewhat smaller sample available in FICSMath survey, we provide new information about the path homeschooled students take to college-level (tertiary) calculus.

Table 1 shows the type of high school that has been included in our analysis and the gender of the respondents. Excluded from the data in Table 1 are 78 respondents, or 0.9% of the data, who did not disclose the type of high school attended. The 190 students who reported homeschooling will be the main focus of our analysis and subsequent discussion. A notable feature of the FICSMath sample is that, across school types, college students taking single-variable calculus are disproportionately male (56%–62%), compared with the overall gender composition of college undergraduates. Data from the 2012 Current Population Survey (CPS) indicate that just 44.0% of undergraduate students were male (U.S. Census Bureau, 2012, Table 5).

Table 2 shows that students in the FICSMath sample were predominantly White (65%–83%), and non-Hispanic (81%–90%), and that most students used English while at home (84%–92%). Among those students who reported homeschooling in high school, Table 2 indicates that those who homeschooled were likewise predominantly White (78%), with single-digit percentages of other racial backgrounds, and predominantly non-Hispanic (86%). Most homeschoolers (92%) used English while at home.

Readers surprised by the above descriptors should note that the K–12 and undergraduate populations in the United States differ in a number

TABLE 1 Reported Type of High School Where a Majority of High School Education Was Received Among Tertiary Calculus Students Responding to the FICSMath Survey, 2009 (N = 8,999)

	Gender			
High School Type	Male (%)	Female (%)	NR (%)	Number (%)
Homeschool	111 (58)	68 (36)	11 (6)	190 (2.1)
Public	4,819 (62)	2,575 (33)	409 (5)	7,803 (86.0)
Private, Parochial	340 (56)	237 (39)	29 (5)	606 (6.7)
Private, Non-Parochial	204 (61)	107 (32)	21 (6)	332 (3.7)
Public Charter	40 (59)	23 (34)	5 (7)	68 (0.8)

Note. NR = No Response.

TABLE 2 Demographic Background of Tertiary Calculus Students Responding to the FICSMath Survey by Type of High School Where a Majority of High School Education Was Received (N = 8,999)

	School Type				
Variables	Home School (%)	Public (%)	Private, Parochial (%)	Private, Non-Parochial (%)	Public Charter (%)
Race					
White	148 (78)	5,723 (73)	505 (83)	254 (77)	44 (65)
Black	3 (2)	325 (4)	16 (3)	12 (4)	9 (13)
Asian	9 (5)	651 (8)	25 (4)	23 (7)	2 (3)
PI	1 (1)	65 (1)	4 (1)	0 (0)	0 (0)
AI/AN	5 (3)	99 (1)	6 (1)	6 (2)	1 (1)
Other	13 (7)	587 (8)	32 (5)	23 (7)	7 (10)
Not Reported	11 (6)	353 (5)	18 (3)	14 (4)	5 (7)
Ethnicity					
Non-Hispanic	163 (86)	6,816 (87)	545 (90)	299 (90)	55 (81)
Hispanic	15 (8)	682 (9)	49 (8)	17 (5)	8 (12)
Not reported	12 (6)	305 (4)	12 (2)	16 (5)	5 (7)
Home Language					
English	174 (92)	6,541 (84)	560 (92)	288 (87)	58 (85)
Not English	5 (3)	1,004 (13)	36 (6)	30 (9)	7 (10)
Not reported	11 (6)	258 (3)	10 (2)	14 (4)	3 (4)

Note. PI = Pacific Islander; AI/AN = American Indian or Alaska Native.

of ways. U.S. Census data indicate that the current K–12 population is much more diverse than the undergraduate population. As of the 2010–2011 school year, just 54% of current K–12 students identified as “White alone” (compared with 70% of undergraduates), and 77% of current K–12 students identified as non-Hispanic (compared with 90% of undergraduates; NCES, 2012b, Indicator 6).

Such racial and ethnic differences between the undergraduate and K–12 populations are likely the result of a large racial and ethnic matriculation gaps in the United States. Readers are cautioned against leaping beyond the data reported here to conclusions about the path of students in high schools generally, keeping in mind the limits of what we can and cannot report. These data are representative of college undergraduates taking single-variable calculus only, and it is clear that such students are—compared with other college students—disproportionately male and—compared with K–12 students generally—disproportionately White and non-Hispanic. Additionally, the FICSMath survey reports on parent education and support for mathematics at home, both incomplete but helpful indicators of family socioeconomic status (NCES, 2012c).

Figure 1 presents the highest education levels of parents or guardians reported by students in the FICSMath sample. Here, for ease of modeling, we have converted ordinal survey responses (students selected from options: “Did not finish high school,” “High school,” “Some college,” “Four years of

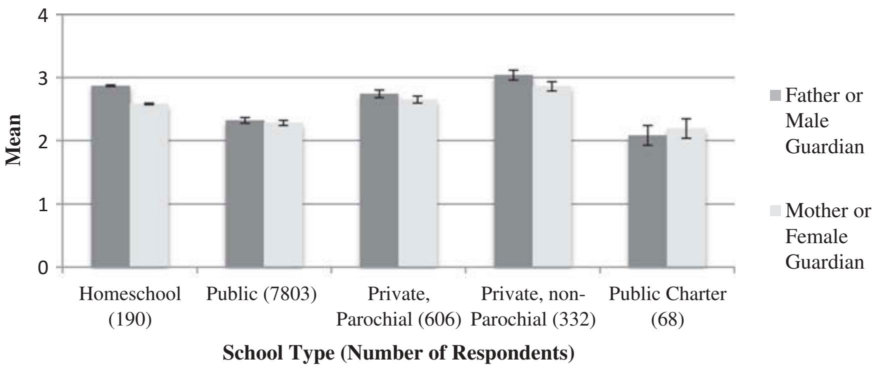

FIGURE 1 Level of father or male guardian's highest level of education and mother or female guardian's highest level of education by type of high school, with the number of calculus students responding to the FICSMath survey (N = 8,999 total).

Note. Scale: 0 = *did not finish high school*; 1 = *high school*; 2 = *some college*; 3 = *four years of college*; 4 = *graduate school*. Error bars indicate 1 standard error.

college," and "Graduate school") to an interval variable (0–4) as a rough indicator of parent attainment throughout our sample. The distribution of parent educational attainment demonstrated broad overlap, with slightly higher levels of parent/guardian educational attainment among those who were homeschooled or who attended private schools (Parochial or non-Parochial), compared with those who attended public or charter schools. Because the distribution of parent education levels violated the normality assumption of analysis of variance (ANOVA) modeling, nonparametric Kruskal-Wallis tests were performed. These tests indicated that these reported parental education differences by school type were significant for both male parent/guardians (H = 218.7, $p < .0001$) and female parent/guardians (H = 153.8, $p < .0001$). However, such significance should be viewed with caution, given skew differences across school types (see Fagerland & Sandvik, 2009), and the results should be interpreted as exploratory only.

What about home support for mathematics? Figure 2 presents the self-reported "degree to which home environment was supportive of math" among students in the FICSMath sample. As with parent education, the distribution of home support for mathematics demonstrated broad overlap. Mean self-reported home support among students who attended public schools was 3.8 (rating scale 0–5; 0 = *not supportive at all*, 5 = *very supportive*), with slightly higher home support among students who homeschooled (4.2), and slightly lower levels of support among students in charter schools (3.4). Given that the distribution of home support violated the normality assumption of ANOVA, a nonparametric Kruskal-Wallis test was performed and indicated that these differences were significant (H = 43.8, $p < .0001$). These distributions did not violate test assumptions.

An additional background characteristic of ongoing interest among homeschool researchers—and worth investigating as a student background

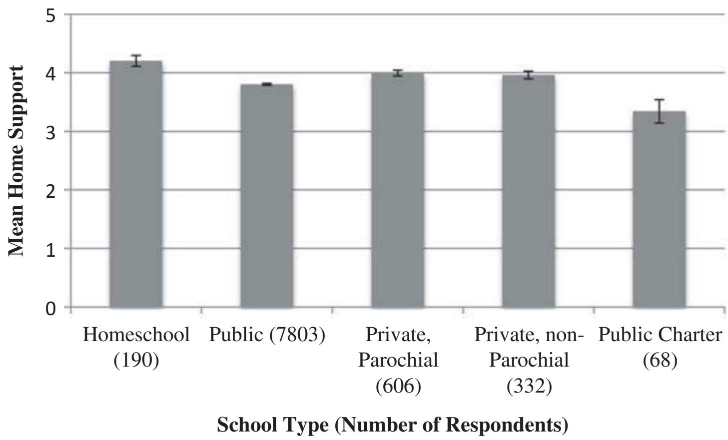

FIGURE 2 Mean of the degree to which home environment was supportive of math by high school type and number of students responding on the FICSMath survey ($N = 8{,}999$ total).
Note. Rating scale 0–5; 0 = *not supportive at all*, 5 = *very supportive*.

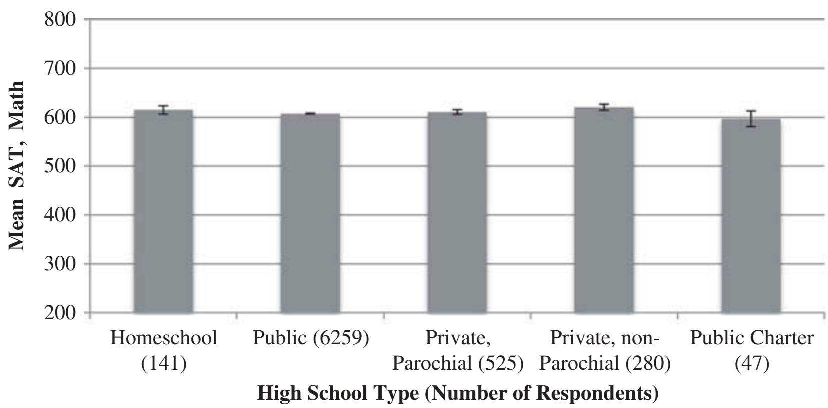

FIGURE 3 SAT Mathematics score of students responding to FICSMath survey, 2009, by type of high school ($N = 7{,}252$ total). Math scores of students who took the ACT converted to SAT math scores per ACT-SAT concordance table (Dorans, 1999).

characteristic in this study—is academic achievement on standardized tests during the high school years. For all their limitations, the SAT and the ACT provide standardized measures of the mathematics skills of students while in high school—and can help characterize the extent to which various high school paths have been successful in preparing students for college calculus. Figure 3 reports the SAT scores of students in the FICSMath dataset by high school type; the scores of students who took the ACT are included in this table using a concordance table provided by Dorans (1999, p. 9); the overall sample mean on the SAT Math section was 608.6 (scale: 200–800).

TABLE 3 Average Grades in College-Level Calculus Among Students Responding to FICSMath Survey by Type of High School Where a Majority of High School Education Was Received (N = 5,526)

High school type	n	Median grade	Mean grade	SE
Homeschool	100	92.0	87.2***	1.219
Public	4,752	84.5	80.6	.202
Private, Parochial	418	84.5	82.3	.610
Private, Non-Parochial	227	84.5	81.9	.891
Public Charter	29	82.0	78.9	3.090

Note. Final course grades reported by college professors. This table excludes students repeating college-level calculus, or who took college-level precalculus. Grades reported on 0–100 point scale. Significance testing via Tukey post-hoc pairwise comparisons, reference category "public."
***p < .001.

Most students across school types reported taking either the SAT or the ACT. For students in traditional public schools, the completion rate was 80.2% (n = 6,259); for homeschoolers the completion rate was 74.3% (n = 141). Distributions of SAT Math scores were generally similar in range and shape but violated normality assumptions,[1] ruling out straight ANOVA tests for significance. Post-hoc Tukey pairwise comparisons of mean SAT Math scores indicated no significant differences by school type, with one exception: the mean score difference between students attending private, non-Parochial schools (624.7) and those attending traditional public schools (607.6) was significant at the $\alpha = 0.05$ level.

In Table 3 we report final course grades for single-variable college calculus by high school type. For this analysis, we excluded students repeating college calculus, or who took bridge mathematics courses after high school (e.g., college-level precalculus), as we were most interested in gaining insight into tertiary calculus performance from students taking different high school paths. This explains the change in homeschool numbers from more than 100 in all previous tables to exactly 100.

Distributions of final course grades in single-variable college calculus were generally similar in range and shape but violated normality assumptions,[2] ruling out straight ANOVA tests for significance. Post-hoc Tukey pairwise comparisons indicated that the difference between mean final course grades of students who homeschooled (87.2 out of 100) and those who attended traditional public schools (80.6 out of 100) was significant at the $\alpha = 0.05$ level.

Among first-time coursetakers, students who attended public, charter, and private schools during high school earned similar final grades in college calculus. Students who homeschooled during high school, however, earned significantly higher grades than students who attended traditional public schools ($\alpha = 0.05$). Even though the homeschoolers had the highest average grade, their advantage over students from school types other than

TABLE 4 Full Linear Regression Model of Average Grades in College-Level Calculus Among Students Responding to FICSMath Survey by Type of High School Where a Majority of High School Education Was Received and Background Characteristics ($N = 5{,}701$)

Student background characteristics	B	SE B	β
Intercept	55.212	2.304	–
Homeschool	4.357	1.710	.042*
Public	−1.262	1.457	−.031
Private, Parochial	.087	1.474	.002
Private, Non-Parochial	−1.260	1.555	−.019
Public Charter	−.432	2.826	−.002
Gender	−3.664	.409	−.131***
White	1.822	1.175	.048
Black	−.441	1.399	−.006
Asian	.849	1.206	.017
Pacific Islander	2.900	2.185	.020
American Indian/Alaska Native	−2.068	1.677	−.018
Other race	.625	1.443	.010
Hispanic origin	−.500	1.146	−.008
English primary home language	−1.979	.868	−.042*
Highest education, male parent/guardian	.245	.205	.021
Highest education, female parent/guardian	.052	.223	.004
Home support for math	.878	.171	.077***
SAT/ACT Math scores	.041	.002	.281***

Note. This table excludes students repeating college-level calculus, or who took college-level precalculus. School type, race, ethnicity, and home language coded as 0 = no, 1 = yes. Gender coded as 0 = female; 1 = male. Math scores of students who took the ACT converted to SAT math scores per ACT-SAT concordance table (Dorans, 1999). "Home support for math" coded on a 0–5 rating scale; 0 = *not supportive at all*, 5 = *very supportive*.
*$p < .05$; ***$p < .001$.

public schools did not reach significance. This may be due in part to the relatively low numbers in this school type—and accordingly low statistical power.

Finally, we predicted student performance in tertiary calculus from school type in multivariate linear regression models. All predictors discussed above (school type, gender, race, ethnicity, home language, parental education, home support for mathematics, and SAT/ACT math scores) were included in an initial multivariate model. This full model is presented in Table 4, with predictors grouped by conceptual area.

Notably, just five predictors in the initial (full) model appeared to demonstrate significance—homeschooling, gender, English as the primary home language, home support for mathematics, and SAT/ACT mathematics score. None of the other school types appeared likely to contribute to a final (reduced) model.

A final (reduced) model was generated from this initial model by stepwise regression, wherein nonsignificant predictors were deleted one at a time until only statistically significant items remained (criterion for model entry: $\alpha = 0.25$; criterion for retention: $\alpha = 0.05$). The final model included

TABLE 5 Final Linear Regression Model of Average Grades in College-Level Calculus Among Students Responding to FICSMath Survey by Type of High School Where a Majority of High School Education Was Received (N = 5,701)

Student background characteristics	B	SE B	β
Intercept	54.220	1.369	—
SAT/ACT Math scores	.041	.002	.280
Gender	−3.652	.405	−.130
Home support for math	.962	.164	.085
Homeschool	5.186	1.460	.050

Note. All predictors significant at $p < .001$ and ranked by β. This table excludes students repeating college-level calculus, or who took college-level precalculus. Math scores of students who took the ACT converted to SAT math scores per ACT-SAT concordance table (Dorans, 1999). Gender coded as 0 = female; 1 = male. "Home support for math" coded on a 0–5 rating scale; 0 = *not supportive at all*, 5 = *very supportive*. "Homeschool" coded as 0 = no, 1 = yes.

four of the predictors identified in the initial model (homeschool status, gender, home support for mathematics, and SAT/ACT mathematics score). The final model also saw one predictor demonstrating significance in the initial model removed (English as the primary home language). The final (reduced) model is presented in Table 5. The number of homeschool students in the final model was 100. No other high school types survived in the model, thus they are not shown in Table 5.

The most powerful predictor of final college calculus course grades appeared to be SAT/ACT math scores. The parameter estimate for SAT/ACT math scores (scale of 200–800 points) may be interpreted as "An SAT/ACT math score increase of 1 point predicted a final college calculus grade increase of .041 points." An increase in SAT/ACT math scores of 1 standard deviation (here, 100.1 points), would therefore predict a final college calculus grade increase of 4.1 points.

Being female, reporting supportive home environments for mathematics, and homeschooling were also found to be successful predictors of higher final college calculus grades. For homeschooling, the parameter estimate of 5.2 may be interpreted as "Homeschooling (versus enrollment in a traditional school type) predicted a final college calculus grade increase of 5.2 points." The variability captured from the FICSMath dataset was 10.42% and 0.24% for the controls and the added homeschool variable, respectively. The total variability captured was 10.66%. While the homeschool variable captured a comparatively small percentage of the variability, it is important to recognize that no other school type survived the model.

LIMITATIONS

Importantly, the nature of the dataset restricts its generalizability to *only* those students who made the leap from high school mathematics to tertiary calculus, with an obvious selection bias toward the upper reaches of mathematics ability and affinity, vis-à-vis the general high school population. This limitation also applies to the groups of homeschoolers. Readers are warned not to draw broad conclusions from this work about "all students who homeschool." *How restricted are generalizations made from this work?* With respect to high school graduation, NCES estimated that the national Averaged Freshman Graduation Rate for 2009–2010 (most recent data; includes those who homeschooled) was 78.2% (Stillwell & Sable, 2013, p. 4). College matriculation has been estimated at 68.2% of high school graduates (2-year average [2010 & 2011]; includes 2- and 4-year colleges; NCES, 2012a, Table 236). And the most recent examination of college course taking indicated that roughly 32.5% of bachelor's degree recipients in 2007–2008 earned credit for college calculus (NCES 2013b, Table 12). So the students included in the FICSMath dataset and reported here are a subset of those who attended high school, certainly not a majority. Yet there is still some use in these estimates, and it is worth considering what these estimates may capture. If it is reasonable to characterize students who graduated from high school, went to college, and enrolled in calculus as "successful" in the domain of mathematics achievement—then the group of students included in the FICSMath dataset represent something of an upper limit. These students are the ones who have done well in mathematics. Likewise, it seems reasonable to think that those not in the dataset—who did not take calculus, who did not go to college, or who did not graduate from high school—are the ones who have been (as a group) less successful in mathematics. The findings we present may shed some light on the achievement of students who have done well in mathematics, but are likely silent on the achievement of the majority who have not.

A second limitation is that the FICSMath dataset is predominantly based on student surveys (with the exception of professor-provided final course grades), so the findings here include limitations all surveys face: What students retrospectively report about parent education levels or home support, for example, may not align precisely with the same data parents themselves would provide.

DISCUSSION

The title of this article asks a single question: *Are homeschoolers prepared for college calculus?* While a complete answer this question remains elusive, the evidence from the FICSMath survey presented above is worth considering in some detail.

First, the racial and ethnic backgrounds of students in the FICSMath sample appear comparable to undergraduates nationwide. Majorities of students in the FICSMath dataset (currently taking single-variable college calculus)—homeschooled or otherwise—were male, White, non-Hispanic, and used

English while at home during the high school years. The most recent available U.S. Census data (for the 2010–2011 school year) appear similar: 70% of U.S undergraduates identified as "White alone" (70%), and 90% identified as non-Hispanic (NCES, 2012b, Indicator 10); we do not have reliable data about previous home language use among college students. The 190 students in the FICSMath sample who reported homeschooling for a majority of high school also appear to be demographically comparable to students who attended other types of high schools by gender, race, ethnicity, or home language; we found no evidence of differential selection into homeschooling by these factors.

Second, we examined parent/guardian education and home support for mathematics while in high school. Parents of homeschoolers appearing in the FICSMath dataset appear to have had about as much education as parents of students who attended Parochial or non-Parochial private schools (averaging approximately "four years" of college), and more education than those whose children attended public or charter schools (averaging "some" college). Homeschoolers also reported higher scores for "degree to which home environment was supportive of math," (averaging 4.2 on a 5-point scale) compared to all other school types (averaging between 3.4 and 4.0 on a 5-point scale). While both findings may make some amount of intuitive sense, we cannot overemphasize that we do not have evidence of a causal relationship in these data; a range of mechanisms are possible.

Third, in Figure 3 we examined SAT Math scores (and concordant ACT Math scores). We found no significant differences between mean SAT Math scores of students who reported homeschooling and those who attended other types of high schools (mean scores ranged between 596–618), with the exception of students who attended private, non-Parochial schools, whose SAT Math score average (625) was significantly higher than that of students who attended traditional public schools. Such a "no difference" finding comparing students who homeschooled to students from other types of schools appears slightly more positive than the findings of Belfield (2005) and Qaqish (2007), who reported slightly lower SAT Math and ACT Math scores among homeschoolers, respectively.

Fourth, in Table 3 we examined final course grades in single-variable college calculus. We found that, among first-time calculus students who had not taken college precalculus, students who homeschooled earned significantly higher final grades (Mean: 87.2 out of 100) than students who attended all other school types (Means ranged from 78.9–82.3 out of 100). We were intrigued by this finding, as it raises a number of questions. The demographic backgrounds of students who homeschooled appear similar to students who attended other types of high schools, including academic achievement in mathematics, yet they appear to earn higher college calculus grades. Why? Are we just seeing an artifact of differential selection into—or out of—college calculus, based on previous coursework, confidence, or other factors? Or is there some sort of beneficial "treatment effect" of homeschooling during high school that may carry over into college mathematics coursework? Again, we are unable to speak to these questions with the FICSMath dataset, but they highlight the need for further examination of homeschooling during the precollegiate years and the transition into college and careers.

Fifth, and finally, we examined the extent to which any of the predictors discussed throughout this article could successfully contribute to a model predicting final grades in single-variable college calculus. Our initial (full) model in Table 4 affirmed that homeschooling did show an effect that was significant and positive with all of the discussed controls included. We were somewhat surprised to see controls such as race, Hispanic origin, and parent education levels contribute little to the initial model—particularly given that parent education levels could conceivably contribute to a homeschooled student's experiences in mathematics. Yet it appears that "home support for mathematics" is a better (positive and significant) predictor of college calculus grades—yielding some evidence that parental support for mathematics matters more than parental education. The final (reduced) model, presented in Table 5, affirms a range of predictors determined significant, though the magnitude of each varied considerably. Most powerful were SAT/ACT math scores (our proxy measure for mathematics skills during high school), along with gender and home support for mathematics. Interestingly, although the FICSMath sample was found to be disproportionately (63%) male, we found that being male predicted lower final college calculus course grades (a drop of −3.7 points with a Y chromosome).

Our main interest in this article was the path of students by high school type—particularly those students who reported homeschooling. Homeschooling demonstrated significance as a predictor and is included in the final model (no other school type demonstrated significance), and the magnitude of the effect of homeschooling (versus not) appears to be considerable. A predicted final college calculus score gain of more than 5 points, or roughly half a grade, is certainly meaningful for students and worth consideration in future work.

There remains much work to be done in the area of homeschool research. For example, *Why do the students who homeschooled earn higher average college calculus grades than others?* Is this due to the impact of homeschooling as a treatment during the high school years? Are we seeing evidence of distinct student traits (e.g., if students who homeschooled were more likely than others to seek academic supports in college, ultimately earning higher grades)? Selection effects into or out of college calculus? Is in-school learning so bad that homeschoolers benefit from staying away? FICSMath is designed to explore some aspects of the mathematics experiences of students while in high school—but as we have noted above, the precise nature and average duration of, and course taking experiences during, homeschooling remain unknown, and what we have reported here indicates the worth of expanded attention in the future.

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NOTES

1. Via Kolmogorov-Smirnov test for large-n public schools, Shapiro-Wilk for other school types.
2. See Note 1.

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