Expanding STEM Opportunities Through Inclusive STEM-focused High Schools

Abstract: Inclusive STEM high schools (ISHSs) admit students on the basis of interest rather than competitive examination. This study examines the central assumption behind these schools--that they provide students from population subgroups under-represented in STEM with experiences that equip them academically and attitudinally to enter and stay in the STEM pipeline. Hierarchical modeling was applied to data from student surveys and state longitudinal data records for 5,113 students graduating from 39 ISHSs and 22 comprehensive high schools in Texas and North Carolina. Compared to peers from the same demographic group with similar grade 8 achievement levels, under-represented minority and female ISHS students in both states were more likely to undertake advanced STEM coursework. Hispanics in Texas and females in both states expressed more STEM career interest in grade 12 if they attended an ISHS. The impact of ISHS attendance on GPA and test scores varied by subgroup and measure.

Keywords: STEM education, school reform, equity, STEM school

The stark contrast between the demographic composition of the U.S. population as a whole and that of science, technology, engineering, and mathematics (STEM) college majors and professionals has been a target of concern in economic and educational policy circles for some time (National Academies, 2005, 2011; National Science Foundation, 2014; PCAST, 2010). This disparity raises issues not only for national economic competitiveness but also for those individuals whose opportunities are limited (National Science Board, 2014). STEM occupations are among those growing fastest in the U.S. economy (National Science Board, 2014). People in STEM jobs earn more than those in other jobs; those with STEM bachelor's degrees have higher earnings than individuals with degrees in other fields, even when they enter non-STEM professions (Russell & Atwater, 2005).

The same proportion of African American and Hispanic students as white students express interest in STEM careers (Herrera & Hurtado, 2011), but smaller percentages declare and complete STEM majors (National Science Foundation, 2014). Research exploring the reasons behind the smaller percentage of African Americans, Hispanics, and women completing STEM degree programs point to discrepancies in high school experiences. Lower test scores of students from under-represented minorities in mathematics and science can be accounted for to a large extent by the fact that these students complete fewer advanced mathematics and science courses during high school (National Science Board, 2014). For example, African American students comprise 16% of the high school population but only 8% of high school students

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enrolled in calculus courses; for Latinos, the corresponding percentages are 21and 12% (Office for Civil Rights, 2014).

Some of this discrepancy in math and science course enrollment in high school among different student subgroups is explained by the lack of advanced course offerings in high schools with large concentrations of students from under-represented ethnic groups. Almost 1 in 5 African American high school students attends a school that does not offer any Advanced Placement (AP) courses; a third of the high schools with the largest concentrations of African American and Latino students do not offer chemistry (Office for Civil Rights, 2014). But it is also true that students from under-represented groups in high schools that do offer advanced STEM courses are less likely than white and Asian males to have taken those courses (Laird, Alt, & Wu, 2009). A study of placement into the advanced math class in a nationally representative sample of racially diverse high schools by Muller, Riegle-Crumb, Schiller, Wilkinson, and Frank (2010), for example, found that African American and Latino students were under-represented relative to white and Asian students even after controlling for gender, parents' education, and score on an intelligence test. Qualitative studies describe the subtle and not-so-subtle pressures that discourage under-represented minorities and girls from taking courses and achieving in subject areas perceived as the domain of Asian and white males (Childress, Doyle, & Thomas, 2009; Margolis, Estrella, Goode, Holme, & Nao, 2008; Schofield, 1995).

Inclusive STEM high schools (ISHSs) have been promoted as one strategy for increasing the representativeness of students entering the "STEM pipeline" by undertaking and completing STEM college majors. A number of private foundations articulated the theory of action that secondary schools could be designed to offer a rigorous curriculum and extensive student supports making it possible to develop STEM interest and readiness for college-level STEM among students from under-represented groups (Carnegie Corporation, 2009; Means, Confrey, House, & Bhanot, 2008). This argument has reached high-level policy circles, with President Obama calling for the establishment of 1,000 additional STEM schools (Obama, 2010). State-level initiatives to create such schools have emerged in Texas, Ohio, North Carolina, Arkansas, Tennessee, Arizona, and Washington.

The creation of STEM high schools with an inclusive mission was a dramatic departure from prior thinking about how to create a pipeline of students entering STEM fields. STEM schools created prior to 2000 were predominantly exam-based schools, using competitive tests to select students who could demonstrate high levels of mathematics and science achievement by grade 8. In contrast, inclusive STEM high schools make an effort to recruit students from under-represented minorities and admit students from their pools of applicants on the basis of interest, using lotteries rather than test scores for selection if the school is over-subscribed. Their goal is to develop STEM talent, rather than to "find" it.

Although they all share this mission of inclusion and college preparation, ISHSs vary widely from each other in terms of many of their design features. Some emphasize a career area, such as engineering or medicine; others seek to provide a well-rounded introduction to STEM, equipping their students for any STEM major. Some emphasize instruction integrating the

various STEM disciplines, while others organize STEM instruction around traditional academic disciplines. Some ISHSs depend on partnerships with colleges or with private industry to offer and support significant portions of their instruction. Some employ a career technical education model that includes preparation for entering a baccalaureate program; some place great emphasis on project-based learning (Lynch, Peters-Burton, & Ford, 2014).

Although the term "STEM" has become familiar in education circles, its definition remains a subject for debate (Committee on Integrated STEM Education, 2014; Brown, Brown, Reardon, & Merrill, 2011; Gerlach 2012; Kelley, 2010; Tsupros, Kohler, & Hallinen, 2009). Some would like to reserve the term for curricular approaches that integrate the science, technology, engineering, and mathematics disciplines (Morrison, 2006; Tsupros, Kohler, & Hallinen, 2009); others would like to restrict it to student-centered approaches to instruction (North Carolina State Board of Education, 2014). For the purposes of our research, we adopt a descriptive rather than a prescriptive stance toward STEM, and use the term as a category including biological, physical, environmental, and medical sciences as well as engineering, information technology, and mathematics (cf. Aschbacher, Li, & Roth, 2010).

We define an inclusive STEM high school as a secondary school or self-contained school-within-a-school that (1) students enroll in on the basis of interest rather than aptitude or prior achievement and that (2) provides more intensive STEM preparation than do regular high schools with (3) the goal of preparing students to succeed in a STEM college major. Note that this definition excludes schools with intensive STEM programs in which some students participate but others do not. We include both schools focused on a particular STEM field requiring a bachelor's degree or more education (e.g., engineering) and schools providing preparation for STEM majors in general in our definition.

Predicting Persistence in STEM

Predictors of the likelihood of undertaking and completing a STEM college major have been studied extensively. College admissions test math scores, high school grade point average, and the level of math and science courses taken in high school have been found to predict entrance into a STEM major in numerous studies (see Adelman, 2006; Astin & Astin 1993; Chen & Weko, 2009; Crisp, Nora, & Taggart, 2009; Mendez, Buskirk, Lohr, & Haag, 2008; Smyth & McArdle, 2004; Tyson, Lee, Borman, & Hanson, 2007; Wang, 2013). Using data from 4,700 students who participated in NELS:88, Maltese and Tai (2011) found that the particular math and science courses taken in high school predicted likelihood of earning a STEM degree in college. A recent analysis of data from the Education Longitudinal Study of 2002 by Wang (2013) found that entry into a STEM college major could be predicted quite well from a model incorporating five high school variables (number of math and science courses taken in high school, math achievement test score at the 12th and 10th grades, math efficacy beliefs, and attitude toward math measured in 10th grade) along with several variables measured at college entry, including receipt of financial aid and belief that one's high school math and science courses provided good

preparation for college-level work. Exposure to more math and science courses was the strongest single predictor of STEM persistence in college in Wang's analyses.

There is a lack of clarity around whether the mechanisms for engagement and persistence in STEM are the same for all student subgroups or vary for under-represented minorities and females. Sadler, Sonnert, Hazari, and Tai (2012) found stark gender differences in the maintenance of STEM career interests across high school: While 70% of male students who said they were interested in a career in a STEM field as high school freshmen also said they had this interest as seniors, only 45% of freshman-year STEM-interested female students did. Male students also express more math self-efficacy than do female students with the same math achievement levels (Eccles, 1994; Watt, 2006). Qualitative research studies have highlighted cultural incompatibilities and competing priorities that are differentially likely to affect the STEM interest and engagement of females and students of both sexes from under-represented minority groups. Nora and Ramirez (2006) describe Hispanic students as more likely than non-Hispanic white students to be discouraged by receiving a lower-than-expected grade. In a similar vein, Wang (2013) found a stronger relationship between early math achievement and math self-efficacy for under-represented minorities than for white and Asian students. Although the development of STEM interest and self-efficacy beliefs may unfold in different ways and be differentially vulnerable for different student subgroups, they appear to have a similar influence on intent to major in a STEM field across subgroups (Elliott, Strenta, Adair, Matier, & Scott, 1996; Smyth & McArdle, 2004; Wang, 2013).

High School Factors Related to STEM Achievement and Persistence

A number of variables under a high school's control appear to be related to a student's maintenance of STEM interest and self-efficacy, which in turn predict likelihood of later pursuing a STEM major. As noted above, the number of math and science courses taken predicts persistence in the STEM pipeline, and schools can offer more or fewer courses and choose to prescribe a more intensive course of study rather than making it optional. Provision of STEM research opportunities and project-based instructional approaches appear to increase students' STEM interest as well, with the latter being particularly important for girls and under-represented minorities (Boaler, 1998; Mergendoller, Maxwell, & Bellisimo, 2006; Ross & Hoagaboam-Gray, 1998).

Aschbacher et al. (2010) conducted a longitudinal, qualitative study of a diverse set of students from six public high schools who expressed strong interest in a science, engineering, or medicine career in grade 10. They found four factors that distinguished between the 55% of these students still interested in STEM careers at the end of grade 12 and the 45% who lost interest: Participation in extracurricular science activities, family priorities with respect to college, family priorities with respect to STEM careers, and messages from school staff about their capabilities in STEM.

Larnell (2013) has described the influence of course placement, in either a higher- or lower-track class, on a student's mathematics identity development. In the Aschbacher et al.

study, students who lost their interest in STEM careers described getting the message that science is "hard" and "not for everyone" as well as experiencing poor, uninspiring teaching, often provided by a series of substitute teachers. Another body of research highlights the importance of out-of-school activities and relationships in complementing school experiences to help students develop STEM interests and a view of themselves as STEM capable (Nasir & Shah, 2011; Sfard, 2008). Such findings can be placed in the broader theoretical context of students' identity formation, with cultural and gender identities sometimes competing with the developing sense of oneself as capable of "doing STEM."

There are a number of grounds for hypothesizing that the effects of attending an ISHS might be especially positive for students from groups under-represented in STEM. First, the expectation that *all* of an ISHS's students participate in the school's intensive STEM program means that these schools avoid the negative messages associated with tracking. At these schools, students from under-represented groups do not get screened out of advanced coursework; nor do they have the opportunity to opt out. ISHSs may be less likely than larger schools using ability tracking to trigger stereotype threat for students from groups under-represented in STEM. Nor can ISHSs address the problem of some students' struggling in advanced mathematics and science classes by placing those students in a lower track: these schools must confront the challenge of providing instruction and student supports that enable all their students to succeed at a college preparatory level.

Second, several lines of research suggest the importance of an under-represented student's peer group on STEM persistence. Riegle-Crumb, Farkas, and Muller (2006), for example, found that even after controlling for a student's achievement level, girls who have same-sex friends with higher grades in math and science are more likely to take advanced mathematics and science courses (boys do not show the same pattern). It seems reasonable to suppose that girls attending ISHSs would be more likely to make friends with girls with good grades in math and science. Other research has found that students from under-represented minorities profit from participating in study groups with others of like ethnicity (Treisman, 1992). Students from groups under-represented in STEM are especially susceptible to negative effects of cues about others' perception that they lack STEM ability, as described in Steele's (2010) work on "stereotype threat." One of the cues students use as to whether they "belong" in an advanced STEM class is simply the proportion of students in the class of their same race, ethnicity, or gender (Larnell, 2013). Because of the ISHS philosophy, admissions policies, and design, advanced math and science courses in an ISHS will have a sizable proportion of under-represented minority students in them.

In this study, we examine the central assumption behind ISHSs--that such schools provide students from population groups under-represented in STEM with experiences that equip them academically and attitudinally to enter and stay in the STEM pipeline. We contrast outcomes for students in ISHSs with those of similar students attending comprehensive high schools without a STEM focus.

This study was conducted in Texas and North Carolina—two states that have made substantial investments in establishing ISHSs. Both of these states also have strong student longitudinal data systems that permit tracking individual students across grades. With support from the Gates Foundation, the North Carolina New Schools Project started a network of 14 innovative schools focused on STEM and later expanded the network, with the goal of establishing 20 STEM-focused schools as part of the state's Race to the Top initiative. In Texas, a public-private partnership for high school reform, the Texas High School Project (THSP), included a $71-million investment in starting new "T-STEM" high schools, announced in December 2005. Through THSP, charter organizations received funding to help defray start-up costs for more than 50 T-STEM high schools conforming to a T-STEM Blueprint describing design features and best practices for inclusive STEM-focused schools (http://www.tstemblueprint.org).

Method

Sample and Recruiting

In both North Carolina and Texas, sampling and recruiting began with the identification of inclusive STEM-focused high schools followed by similar efforts to recruit comparison schools without a STEM focus that served similar student populations. Within the schools entering the study, survey data were collected from 12th graders in the spring of their senior year; and administrative data from grades 8 and 12 for these students were accessed from state longitudinal data systems, as described below. Student surveys were administered in North Carolina schools in school year 2012-13 and in Texas schools in school year 2013-14.

School samples. At the time our project began recruiting schools in North Carolina, the state did not maintain a comprehensive list of ISHSs, so the research team had to identify the population of relevant school-level entities. Out of approximately 600 public high schools in North Carolina, we identified 100 as potentially STEM-focused based on their names or nomination as an inclusive STEM-focused school by a set of state education leaders interviewed for the project. To make sure the STEM-focused schools were targeting under-represented groups, we used state datasets to narrow our list of candidate study schools to those with 35% or more low-income and/or 35% or more under-represented minority (African American and Hispanic) students. (State average proportions for these groups were 49% and 39%, respectively.) These criteria reduced the list of potential North Carolina ISHSs to 73. Next, we conducted phone calls to each candidate school and used a screening protocol to establish whether the school really did have a more intensive STEM program than that required of North Carolina schools for high school graduation and whether the STEM program was schoolwide and not limited to students meeting certain criteria. We also removed schools from our list if they did not currently have a class of 12th-graders, or used test scores for selective admissions. These screens reduced the list of schools meeting our ISHS and study criteria to 24. Four of these schools were in districts that declined to participate in our research, leaving 20 ISHSs of which

12 administered the grade 12 survey (another 6 ISHSs participated in other aspects of our research).

Identification of ISHSs in Texas was relatively straightforward because the Texas Education Agency (TEA) maintains a list of T-STEM schools. (Although THSP funding has expired, TEA runs a T-STEM designation process, certifying those schools that demonstrate their intention to adhere to the elements of the T-STEM Blueprint.) In 2013 there were 77 designated T-STEM schools, 51 of which opened prior to 2012-13, making them eligible for further screening for inclusion in the study. Research team members called these schools to ascertain their level of interest in participating in the study and to verify that they had a 12th-grade class and met the study definition of an ISHS. Of the 42 Texas ISHSs invited to participate, 30 agreed to participate and 27 actually administered the Grade 12 Student Survey. Survey results were returned by 22 large comparison schools, 12 in North Carolina and 10 in Texas.

For each ISHS agreeing to participate, we then sought a matched comparison school in the same state that served similar students and did not offer a schoolwide STEM-focused program. In seeking comparison schools in North Carolina, we reasoned that we could maximize the similarity of students in comparison schools to those in ISHSs if we took the former from districts that did not have an ISHS (reasoning that students like those attending ISHSs would have chosen a STEM-focused school if one were available). In Texas, where there were many more ISHSs, we did not use this strategy. In both states, we strove to identify comparison schools that were similar to the ISHSs in terms of student demographics and average test scores, and were not close to a STEM school (so their students did not have the option of choosing a STEM-focused high school). We produced prioritized lists of non-STEM school matches for each ISHS and proceeded to contact candidate comparison schools in order of quality of match to the ISHS until we found one willing to participate.

Grade 12 Student Survey

The Grade 12 Student Survey was designed to collect data on students' high school experiences in their STEM courses and extracurricular activities related to STEM; overall academic and STEM orientation; academic and personal supports received through their high school; plans for the year following graduation; and interest in STEM majors and careers. Sources of items and scales for the Grade 12 Student Survey included the National Center for Education Statistics' (NCES) High School Longitudinal Study, the Consortium for Chicago School Research's Biennial Chicago Public School Student Survey, and surveys used in SRI's Program Evaluation of the Innovative Technology Experiences for Students and Teachers (ITEST) Program and its Evaluation of the Texas High School Project.

The reliability (Cronbach's alpha) of the Grade 12 Student Survey item scales ranged from .71 to .92. The items comprising the scales used in this study are shown in Appendix A.

State Administrative Data

In North Carolina, we obtained state longitudinal student data from North Carolina Education Research Data Center (NCERDC) for students in our survey sample (who were in

12th grade in 2012-13). From the longitudinal data system, we were able to obtain student demographic information, eighth-grade achievement in reading, mathematics, and science, whether the student took Algebra before ninth grade, and whether the student took the ACT as well as high school weighted GPA and ACT test scores. We were able to link our survey data with the administrative data using the keys that NCERDC provided.

In Texas we conducted the analysis linking student administrative data with our survey data at the Texas Education Research Center (ERC) at University of Texas at Austin. From the Texas ERC data we obtained student demographic information and eighth-grade achievement in reading, math and science, whether a student took Algebra before ninth grade, as well as grade 11 scores on the Texas Assessment of Knowledge and Skills (TAKS) mathematics and science tests.

Analysis

We compared 12th-graders in ISHSs and to those in comparison schools in terms of academic experiences and attitudes, plan and aspirations, high school STEM experiences, and academic achievement, adjusting for student demographic information and eighth-grade achievement indicators. We conducted analyses for all 12th-grade students who responded to our survey, and for African American and female subgroups in both states, as well as for the Hispanic subgroup in Texas. For each set of comparisons, we posited a hierarchical model with student and school levels for each outcome. The ISHS impact was estimated at the school level. We included as student-level covariates being female, African American, Hispanic, economically disadvantaged, limited in English proficiency, special education, either parent having a bachelor's degree, and eighth-grade math, science, and reading achievement, as well as a variable indicating whether a student took Algebra before ninth grade. We included school-level covariates including Title I improvement status (controlling for accountability pressure) and percent economically disadvantaged students. We used multiple imputation to impute missing values for student-level predictors. To clearly present results, we centered all predictors in the HLM model at the average for all students and calculated the model-predicted values for students in ISHSs and comparison schools, respectively. The model-predicted values represent the expected values for the average student, assuming attendance in an ISHS or comparison school respectively, and the difference between the ISHS and comparison expected values indicates the ISHS impact on the student outcome of interest.

Results

Table 1 presents basic descriptive information for the ISHSs and the comprehensive high schools in our comparison group. In North Carolina, there were two significant differences between the two sets of schools. ISHSs had a larger proportion of minority students and had slightly higher attendance rates (95.6% compared to 94%). In Texas, the percentage of low-income and minority students was similar in the two school samples. None of the school-level variables in Table 1 differed significantly for Texas ISHSs and comprehensive high schools.

Table 1
ISHS and Comparison School Samples, by State

Characteristic	North Carolina		Texas	
	ISHSs (n = 12)	Comparison Schools (n =12)	ISHS (n = 27)	Comparison School (n = 10)
Enrollment	753.5	1,120.0	923	1,387
Program Improvement status	.42	.45	.14	.30
Percent minority students	62.6*	38.3	73.4	69.0
Percent low-income students	56.6	52.2	65.6	69.0
Avg. incoming 8th-grade math score	360.0	360.8	NA	NA
Avg. incoming 8th-grade science score	147.7	148.7	NA	NA
Urban or suburban	75.0	45.5	88.0	90.0
Attendance (% days)	95.6**	94.0	95.2	93.9

* ISHS differs from comparison school sample at $p < .05$; ** $p < .01$; *** $p < .001$.
NA = Not Available.

Table 2 shows the background characteristics of the 12th-grade students who took the Grade 12 Student Survey. For the North Carolina students, the most striking difference between students in the two school types was the larger proportion of African American students in the ISHSs: Half of the ISHS students completing the survey were African American compared to only 25% of students in the large comprehensive high schools, $p < .001$. In the Texas sample, the biggest difference between students in the two types of schools were that students in ISHSs were more likely to speak a language other than English in the home (44% versus 30%, respectively, $p < .001$). Three additional differences were smaller in magnitude but statistically significant: ISHS students were less likely to be female (47% versus 52%) or to have a parent working in a STEM-related field (30% versus 37%) but more likely to report having at least one parent with a bachelor's degree (29% versus 23%). Overall, these data give no indication that ISHSs are "creaming" well-to-do or high-performing students from the public school system and suggest that the ISHSs in both states are fulfilling their mission of recruiting students from groups under-represented in STEM. The high proportions of low-income and minority students in ISHSs suggest also that many students from these groups are interested in STEM, as evidenced by their choice to attend an ISHS.

Table 2
Comparison of ISHS and Comparison School Grade 12 Survey Respondents

Characteristic	North Carolina		Texas	
	ISHS (*n* = 574)	Comparison School (*n* = 1,703)	ISHS (*n* = 1,041)	Comparison School (*n* = 1,795)
African American	50%***	25%	11%	11%
Hispanic	10%	8%	67%	66%
Female	55%	50%	47%*	52%
Language other than English spoken at home	11%	8%	44%***	30%
At least one parent with a bachelor's degree	37%	36%	29%***	23%
At least one parent in a STEM-related field	47%	48%	30%***	37%

Source: iSTEM Grade 12 Student Survey administered in 2012-13 in North Carolina and in 2013-14 in Texas.

* ISHS differs from comparison school sample at $p < .05$; ** $p < .01$; *** $p < .001$.

Further analyses were conducted for population subgroups under-represented in STEM for which we had at least 100 students in each type of school. This criterion was met for African American students and females in North Carolina and for Hispanics, African Americans, and females in Texas.

STEM Coursework and Activities

Given the differences in the ethnic compositions of schools in North Carolina and Texas, as well as the states' different policy contexts, we opted to treat our data collections as two iterations of the same design rather than pooling data across states. Tables 3 and 4 show data on students' STEM coursework and activities in North Carolina and Texas schools, respectively. The data in these tables, and all subsequent tables are model-predicted values from the HLM analyses, described previously, and have been weighted to account for students being nested in high schools and adjusted for differences in student demographics, eighth-grade achievement indicators, and school factors.

Perhaps the most striking aspect of Tables 3 and 4 is that the overwhelming majority of pairwise differences between ISHS and comparison school 12th graders, whether for students overall or for subgroups under-represented in STEM, show more positive outcomes in ISHSs. Not all of the differences are large, and many fail to attain statistical significance, but in no case is there a statistically significant advantage for students who attended large comprehensive high schools.

In North Carolina, 12th graders in ISHSs reported more academic experiences relevant to becoming ready for STEM at the college level than did their counterparts in comprehensive high schools. The North Carolina high school seniors overall, the African American subgroup, and

females were more likely to have taken precalculus or calculus, physics, chemistry, and more advanced math and science courses if they attended an ISHS rather than a comprehensive high school. In addition, African American students in North Carolina were significantly more likely to have taken one or more engineering courses and one or more technology courses if they attended an ISHS rather than a comparison school. Students' self-reported grades in math and science classes did not differ for the two types of school. African American students were more likely to have taken an Advanced Placement examination if they attended an ISHS. As one might expect, students overall and both African American and female students reported having engaged in more extracurricular activities related to STEM and more self-selected STEM activities outside of school if they attended an ISHS.

In the Texas Grade 12 Student Survey sample overall, ISHS students reported significantly more STEM coursework and experiences in the form of a higher likelihood of having taken: calculus or precalculus, more advanced science and mathematics courses, one or more technology courses, and one or more engineering courses. They also reported more extracurricular and informal STEM activities outside of school; and were more likely to have taken the ACT or SAT college admissions test and to have taken an Advanced Placement (AP) exam. Female students in Texas ISHSs had the same statistically significant advantages in terms of STEM academic experiences as the total sample, with the exception of likelihood of having taken calculus or precalculus. For this latter variable, the difference for females was in the same direction as for the entire sample (60% for females in ISHSs versus 49% in comparison schools) but it was only marginally significant statistically.

Table 3

STEM Coursework and Activities of North Carolina ISHS and Comparison School Grade 12 Survey Respondents

Item/Scale	All Students		African Americans		Females	
	ISHS (*n* =574)	Comparison School (*n* =1,703)	ISHS (*n* = 382)	Comparison School (*n* =445)	ISHS (*n* =305)	Comparison School (*n* = 841)
Took calculus or precalculus	60%***	38%	55%***	24%	73%***	41%
Number advanced math courses taken	0.99**	0.74	0.84***	0.43	1.17***	0.77
Took physics	32%**	12%	27%**	8%	29%*	8%
Took chemistry	79%**	58%	71%*	46%	90%***	66%
Number advanced science courses taken	0.29**	0.18	.18*	0.08	0.32**	0.18
Took one or more technology courses	64%	58%	69%*	56%	52%	52%
Took one or more engineering courses	46%	23%	55%*	18%	28%*	8%
Got mostly As or As and Bs in mathematics	49%	47%	35%	36%	52%	50%
Got mostly As or As and Bs in science	59%	52%	39%	34%	67%	53%
Number extracurricular STEM activities (scale)	1.66***	0.89	1.77***	0.95	1.37***	0.77
Number informal STEM activities outside of school (scale)	2.28**	2.08	2.29**	2.05	2.12**	1.93
Took ACT or SAT	97%	94%	96%	94%	97%	95%
Took an AP exam	48%	43%	37%*	30%	51%	45%

Source: iSTEM Grade 12 Student Survey administered in 2012-13; HLM weighted data.

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table 4

STEM Coursework and Activities of Texas ISHS and Comparison School Grade 12 Survey Respondents

Item/Scale	All Students		Hispanics		African Americans		Females	
	ISHS (*n* = 1,041)	Comparison School (*n* = 1,795)	ISHS (*n* = 703)	Comparison School (*n* = 1,183)	ISHS (*n* = 118)	Comparison School (*n* = 191)	ISHS (*n* = 486)	Comparison School (*n* = 907)
Took calculus or precalculus	60%*	48%	59%	49%	51%*	33%	60%	49%
Number advanced math	0.93**	0.73	0.98*	0.73	0.74	0.53	0.92*	0.70
Took physics	89%	89%	89%	90%	80%	83%	89%	89%
Took chemistry	92%	93%	93%	93%	85%	87%	93%	92%
Number advanced science	0.42**	0.23	0.43**	0.23	0.34	0.17	0.38*	0.21
Took one or more technology	61%**	40%	64%***	38%	54%*	39%	58%*	34%
Took one or more engineering	58%**	16%	58%***	17%	66%***	22%	54%***	9%
Got mostly As or As and Bs in mathematics	52%	49%	48%	46%	53%	41%	52%	51%
Got mostly As or As and Bs in science	59%	53%	56%	51%	52%	47%	63%	56%
Number extracurricular STEM activities (scale)	1.56**	1.09	1.69**	1.15	1.88	1.50	1.40**	0.95
Number informal STEM activities outside of school (scale)	2.09**	2.03	2.18**	2.06	2.02	2.05	1.96*	1.89
Took ACT or SAT	90%*	83%	88%	84%	89%	79%	90%*	85%
Took an AP exam	63%***	43%	66%***	44%	54%*	31%	62%*	44%

Source: iSTEM Grade 12 Student Survey administered in 2013-14; HLM weighted data.

* $p < .05$; ** $p < .01$; *** $p < .001$.

Hispanic students in Texas ISHSs had statistically significant advantages over those in large comprehensive high schools in terms of all of the same variables that were significant for the total student sample with the exceptions of having taken calculus or precalculus (reported by 59% of Hispanic students in ISHSs compared to 49% in comprehensive high schools) and having taken the ACT or SAT (88% versus 84%).

There were somewhat fewer statistically significant differences for the smaller samples of African American students in Texas ISHSs and comprehensive high schools. Those variables where there were statistically significant advantages for African American students who attended a Texas ISHS were completion of calculus or precalculus, taking one or more technology courses, taking one or more engineering courses, and getting mostly As or As and Bs in mathematics.

Attitudes Toward STEM Subjects

Student attitudes toward STEM subjects are shown in Tables 5 and 6 for North Carolina and Texas students, respectively. North Carolina students in the ISHSs expressed a stronger science identity across the board. In addition, students overall and females but not African American students expressed a stronger math identity if they had attended an ISHS. There were no statistically significant differences in students' sense of math or science efficacy in the North Carolina sample. Nor did students in the two types of school differ in terms of their sense of the tradeoff between STEM and other aspects of their lives, regardless of whether or not they were from a group under-represented in STEM.

Texas ISHS students overall and Hispanic students expressed a stronger science identity and reported more persistence in the face of difficulty in a math or science class than their counterparts in large comprehensive schools. In addition, Hispanic students expressed a stronger math efficacy if they attended an ISHS. Again, There were fewer statistically significant differences for females and the relatively small Texas African American sample. The only statistically significant difference for these subgroups was reported persistence in the face of difficulty in a math or science class, $p < .05$.

Students' Plans and Aspirations

Twelfth graders' aspirations for college and careers are shown for the North Carolina and Texas samples in Tables 7 and 8, respectively. The level of academic aspiration in terms of expectation for postsecondary degree completion tended to be higher among students in ISHSs. ISHS students expressed higher aspirations than students in comprehensive high schools in the case of plans to earn a master's or higher degree for students in North Carolina and plans to enter a 4-year college directly after high school graduation, to earn a bachelor's or higher degree, and to earn a master's or high degree for students in Texas. In addition, ISHS students consistently expressed a higher level of interest in pursuing a STEM career than did students in comparison schools. Significant differences favoring ISHSs were found in both states for students overall and for females. STEM career interest was significantly higher for Hispanic students in Texas ISHSs as well. The same trend toward higher STEM career interest in ISHSs is apparent for African American students in both states, but in neither case did it rise to the level of statistical significance.

Table 5

STEM Attitudes of North Carolina ISHS and Comparison School Grade 12 Survey Respondents

Item/Scale	All Students		African Americans		Females	
	ISHS (n = 574)	Comparison School (n = 1,703)	ISHS (n = 382)	Comparison School (n = 445)	ISHS (n = 305)	Comparison School (n = 841)
Math identity	2.43**	2.28	2.40	2.33	2.34*	2.21
Science identity	2.61***	2.37	2.38**	2.23	2.59**	2.39
Math efficacy	2.58	2.61	2.59	2.65	2.49	2.56
Science efficacy	2.90	2.83	2.80	2.82	2.94	2.75
Persistence in math or science class	2.89*	2.59	2.88	2.62	2.99*	2.69
STEM opportunity tradeoff – Time	2.21	2.30	2.14	2.22	2.12	2.22
STEM opportunity tradeoff – Social	1.72	1.74	1.70	1.72	1.64	1.66

Source: iSTEM Grade 12 Student Survey administered in 2012-13; HLM weighted data.
* $p < .05$; ** $p < .01$; *** $p < .001$.

Table 6

STEM Attitudes of Texas ISHS and Comparison School Grade 12 Survey Respondents

Item/Scale	All Students		Hispanics		African Americans		Females	
	ISHS (n = 1,041)	Comparison School (n = 1,795)	ISHS (n =703)	Comparison School (n = 1,183)	ISHS (n = 118)	Comparison School (n = 191)	ISHS (n = 486)	Comparison School (n = 907)
Math identity	2.23	2.27	2.33	2.25	2.23	2.18	2.10	2.20
Science identity	2.30*	2.29	2.41*	2.27	2.15	2.16	2.20	2.22
Math efficacy	2.60	2.62	2.71*	2.63	2.76	2.57	2.47	2.57
Science efficacy	2.62	2.76	2.81	2.81	2.54	2.76	2.54	2.71
Persistence in math or science class	2.36**	2.24	2.46*	2.14	2.57*	2.06	2.41*	2.30
STEM opportunity tradeoff – Time	2.26	2.36	2.37	2.34	2.26	2.25	2.12	2.31
STEM opportunity tradeoff – Social	1.69	1.77	1.77	1.75	1.74	1.80	1.60	1.74

Source: iSTEM Grade 12 Student Survey administered in 2013-14; HLM weighted data.
* $p < .05$; ** $p < .01$; *** $p < .001$.

Table 7
Plans and Aspirations of North Carolina ISHS and Comparison School 12th Graders

Item/Scale	All Students		African Americans		Females	
	ISHS (n = 574)	Comparison School (n = 1,703)	ISHS (n = 382)	Comparison School (n = 445)	ISHS (n =305)	Comparison School (n = 841)
Plan to enter 4-year college next fall	52%	45%	57%	47%	55%	51%
Plan to earn bachelor's or higher degree	81%	75%	88%	83%	81%	80%
Plan to earn master's or higher degree	0.39*	0.30	0.41	0.29	0.45	0.34
STEM career interest (scale)	89%**	82%	92%	86%	87%**	76%

Source: iSTEM Grade 12 Student Survey administered in 2012-13; HLM weighted data.
* p < .05; ** p <.01; *** p <.001.

Table 8
Plans and Aspirations of Texas ISHS and Comparison School 12th Graders

Item/Scale	All Students		Hispanic		African Americans		Females	
	ISHS (n = 1,041)	Comparison School (n =1,795)	ISHS (n = 703)	Comparison School (n =1,183)	ISHS (n = 118)	Comparison School (n =191)	ISHS (n =486)	Comparison School (n =907)
Plan to enter 4-year college next fall	51%*	37%	50%*	35%	46%	39%	54%*	41%
Plan to earn bachelor's or higher degree	80%*	73%	78%	71%	76%	78%	82%*	75%
Plan to earn master's or higher degree	0.33	0.28	32%	25%	27%	31%	3741%	31%
STEM career interest (scale)	88%**	83%	90%**	85%	89%	78%	87%**	80%

Source: iSTEM Grade 12 Student Survey administered in 2013-14; HLM weighted data.
* p < .05; ** p <.01; *** p <.001.

Qualities of High School STEM Experiences

The data in Tables 3 – 8 suggest that after controlling for a comprehensive set of school- and individual-level variables, STEM coursework, activities, attitudes, and career interest are stronger not only for ISHS students overall but also for female students and for students from the dominant minority subgroup within each state if they attended an ISHS. To gain some insight into the high school experiences that might account for these outcomes, the Grade 12 Student Survey included items asking students about their experiences with classroom instruction and school supports for making college and career plans. Differences between reports of students in ISHSs and comparison schools were found on these measures as well, as shown in Tables 9 and 10.

In North Carolina, 12th graders in ISHSs were more likely than those in comparison schools to describe their mathematics classes as having features associated with instruction of advanced skills and deeper learning, such as use of project-based learning and the tools used by math and science professionals. They were also more likely to describe their mathematics instruction as incorporating other STEM subjects. A similar but less pronounced (and statistically nonsignificant) pattern was found in survey reports for science classes. North Carolina ISHS students described their teachers as having higher expectations for student success and as having greater respect for students than did North Carolina comparison school students. Finally the number of college and career readiness supports North Carolina students experienced was higher in ISHSs than in comparison schools. Importantly, ISHS African American and female students also reported these same experiences to a significantly greater extent than their counterparts in comparison schools.

In Texas, the pattern of differences between reported school experiences in ISHSs and in large comprehensive high schools were similar to those found in North Carolina (see Table 10). Twelfth graders in ISHSs were more likely than those in comparison schools to describe their mathematics classes as integrating content from other STEM subjects. Texas ISHS students described their teachers as having higher expectations for student success and as having greater respect for students than did Texas comparison school students. As in North Carolina, Texas ISHS students reported using more college and career readiness supports than did their peers in comparison schools, $p < .01$, and they reported a higher frequency of talking with counselors about academic and career plans, $p < .05$.

The pattern of significant differences between ISHS and comparison school students in Texas was the same for the Hispanic subgroup as for the student sample as a whole. All of the same statistically significant advantages for students in ISHSs pertained to females as well with the exception of more talking with college counselors about college and careers. In addition, female students in ISHSs reported significantly more integration of other STEM subjects into their science classes, $p < .001$. Texas African American students too tended to report having more of these experiences if they attended an ISHS, but with the smaller African American samples, the only variable that attained statistical significance was math and science teachers' respect for students, $p < .05$.

Table 9

High School STEM Experiences Reported by Students in North Carolina ISHS and Comparison Schools

Item/Scale	All Students		African Americans		Females	
	ISHS (n = 574)	Comparison School (n = 1,703)	ISHS (n = 382)	Comparison School (n = 445)	ISHS (n = 305)	Comparison School (n = 841)
Math instruction included advanced skills (scale)	3.54***	3.16	3.64**	3.15	3.55**	3.14
STEM integrated into math instruction (scale)	3.14**	2.84	3.13*	2.77	3.08*	2.72
Science instruction included advanced skills (scale)	3.79	3.61	3.81	3.57	3.84	3.62
STEM integrated into science instruction (scale)	3.55	3.40	3.68	3.41	3.56	3.41
Teachers' level of expectation	3.11***	2.78	3.20***	2.76	3.06**	2.80
Teachers' respect for students	3.19***	2.89	3.16***	2.82	3.17***	2.92
Number of college and career readiness supports used	5.84***	4.45	7.07***	5.68	6.29***	4.71
Talking with teachers about academic and career plans	2.11	2.20	2.28	2.30	2.23	2.47
Talking with counselors about academic and career plans	2.74	2.73	2.64	2.45	2.90	2.94

Source: iSTEM Grade 12 Student Survey administered in 2012-13; HLM weighted data.

* $p < .05$; ** $p < .01$; *** $p < .001$.* $p < .05$.

* ISHS differs from comparison school sample at $p < .05$; ** $p < .01$; *** $p < .001$.* $p < .05$.

Table 10

High School STEM Experiences Reported by Students in Texas ISHS and Comparison Schools

Item/Scale	All Students		Hispanics		African Americans		Females	
	ISHS (n = 1,041)	Comparison School (n = 1,795)	ISHS (n = 703)	Comparison School (n = 1,183)	ISHS (n =118)	Comparison School (n = 191)	ISHS (n = 486)	Comparison School (n =907)
Math instruction included advanced skills (scale)	2.94	2.98	3.10	2.98	3.12	3.04	2.83	2.94
STEM integrated into math instruction (scale)	2.83**	2.72	2.99***	2.74	2.87	2.75	2.66**	2.60
Science instruction included advanced skills (scale)	3.28	3.29	3.43	3.24	3.47	3.38	3.23	3.25
STEM integrated into science instruction (scale)	3.25	3.22	3.40	3.25	3.41	3.31	3.22***	3.19
Teachers' level of expectation	2.81***	2.72	2.96***	2.74	2.87	2.69	2.68*	2.71
Teachers' respect for students	2.84*	2.83	3.03*	2.86	2.93*	2.77	2.74*	2.82
Number of college and career readiness supports used	5.84**	5.06	6.61**	5.44	6.08	5.38	5.91*	5.28
Talking with teachers about academic and career plans	2.28	2.26	2.43	2.24	2.25	2.09	2.20	2.36
Talking with counselors about academic and career plans	2.25*	2.05	2.47**	2.05*	2.12	1.93	2.24	2.15

Source: iSTEM Grade 12 Student Survey administered in 2013-14; HLM weighted data. * $p < .05$; ** $p < .01$; *** $p < .001$.
* ISHS differs from comparison school sample at $p < .05$; ** $p < .01$; *** $p < .001$.

High School Achievement Measures

The stated mission of ISHSs is to provide a secondary education that will equip their graduates for postsecondary work, including a STEM major if they choose to pursue one. Tables 11 and 12 show the high school achievement variables most relevant to college readiness. For North Carolina, these are weighted GPA, ACT Math score, and ACT Science score, all of which were obtained from the state's longitudinal student data system.

Table 11

High School Outcomes for Students in North Carolina ISHS and Comparison Schools

Item/Scale	All Students		African Americans		Females	
	ISHS (n = 574)	Comparison School (n = 1,703)	ISHS (n = 382)	Comparison School (n = 445)	ISHS (n = 305)	Comparison School (n = 841)
Weighted GPA	3.45**	3.25	2.97**	2.70	3.63**	3.41
ACT Math	19.50	19.35	17.64	17.34	19.44	19.40
ACT Science	19.24*	18.34	16.66	15.75	19.12	18.37

Source: State longitudinal student data system at NCERDC.

* $p < .05$; ** $p < .01$; *** $p < .001$.* $p < .05$.

Table 12

High School Outcomes for Students in Texas ISHS and Comparison Schools

Item/Scale	All Students		Hispanics		African Americans		Females	
	ISHS (n = 1,041)	Comparison School (n = 1,795)	ISHS (n = 703)	Comparison School (n = 1,183)	ISHS (n = 118)	Comparison School (n = 191)	ISHS (n = 484)	Comparison School (n = 947)
TAKS Math	2175.96*	2237.20	2242.21	2209.89	2151.76	2133.99	2247.43	2223.45
TAKS Science	2144.65*	2200.84	2220.09	2186.29	2154.89*	2084.20	2233.38*	2192.40

Source: Texas longitudinal student data; HLM weighted data.

* $p < .05$; ** $p < .01$; *** $p < .001$.

In North Carolina, students overall, African American students, and female students in ISHSs had higher weighted GPAs than did students from similar backgrounds in comprehensive high schools. ISHS students overall had higher ACT Science scores, but they did not exceed their peers in comprehensive high schools in terms of ACT Mathematics scores. African American and female students tended to have very similar ACT scores whether they attended an ISHS or a comprehensive high school.

The Texas student data system did not contain GPA or ACT scores for students in our survey sample, but did provide scores on the state TAKS Mathematics and Science tests taken at the end of grade 11. Texas students overall had higher TAKS Mathematics and Science scores in ISHSs than in large comprehensive high schools. In the subgroup analyses, Texas African American and female students also had higher ACT Science scores if they attended an ISHS, $p < .05$.

Discussion

Findings from North Carolina and Texas suggest that inclusive STEM-focused high schools implemented at scale do indeed attract and serve large proportions of students from groups historically under-represented in STEM fields. It could be argued that this result alone, makes their establishment worthwhile because it may be inferred that ISHSs nurture STEM identity. Half of the 12th graders in North Carolina ISHSs were African American and two-thirds of those in Texas ISHSs were Hispanic. ISHS seniors in both states were roughly 50% female, and in Texas ISHS students were more likely than their counterparts in comparison schools to speak a language other than English at home. If STEM identity is an issue that affects participation of students in under-represented groups in STEM careers, then these two states are successfully developing STEM opportunities that show students, families, and the communities that students who are STEM-oriented need not be limited to Asian and white males. Over time, the increasing number of "STEM capable" students from under-represented groups could become a critical mass to upend stereotypes about who "does STEM."

With respect to the question of whether or not students from under-represented groups are graduating from ISHSs with the academic foundations and levels of motivation needed for undertaking STEM study in college, the data are encouraging. In North Carolina, African American, and female students are significantly more likely to complete calculus or precalculus, chemistry, and physics if they attend an ISHS. These subjects prepare students for college success in STEM fields (Bottia, Stearns, Mickelson, Moller, & Parker, 2015). In terms of attitude, ISHS students have stronger math and science identities and are more likely to be interested in a career in a STEM career field. However, we suspect that the nurturing opportunity structures and supports that ISHS students encounter in high school must also be employed and nurtured in college, if these young people are to be retained in the STEM pipeline (Maton, Hrabowski, & Schmitt, 2000; Treisman, 1992).

A similar pattern of more favorable outcomes was found in Texas ISHSs. Texas ISHS students from under-represented groups differed from their peers in other schools in several

important ways. Hispanics expressed a stronger science identity, a stronger math efficacy, were more likely to report persisting in the face of difficulty in a math or science class, engaged in more STEM extracurricular activities, had a stronger STEM orientation outside of school, and were more likely to be interested in a STEM career. African American ISHS 12th graders were more likely to have taken calculus or precalculus, to report getting As or a mix of As and Bs in their math classes, to have persisted in the face of difficulty in their math and science classes, and to be interested in STEM careers. Female students were more likely to have taken calculus or precalculus, technology, and engineering courses; reported more persistence in the face of difficulty in a math or science class; took more AP examinations; were more engaged in STEM extracurricular and out-of school activities; and were more likely to be interested in a STEM career than their comparison school peers.

One of the most concrete and noteworthy advantages we found for the ISHSs' STEM programs was taking precalculus or calculus in high school. For many STEM majors, completion of those courses during high school predicts taking college calculus in freshman year, an important hurdle for STEM majors—and an accomplishment achieved by only 37% of high school graduates nationwide (Riegle-Crumb et al., 2006). Qualitative studies of ISHSs (Lynch, Peters-Burton, & Ford, 2014) have found that students enter these schools with varied and sometimes weak mathematics preparation; preparing students for the level of mathematics required in STEM majors has proven to be one of the biggest challenges in inclusive ISHSs where students are selected on the basis of interest rather than prior mathematics achievement. The students entering ISHSs may be as many as three years behind grade-level expectation in math when they enter ninth grade. Readying these students for college and for STEM majors requires intensification of mathematics instruction, over and above the annual progress achieved in typical high schools. The data reported here for ISHSs in North Carolina and Texas show that these schools are getting a majority of their students through at least precalculus in high school. On the other hand, mathematics test scores were no higher for North Carolina students on the ACT Math and no higher for the under-represented groups on the TAKS Math in Texas. But the fact that these large-scale assessments do not attempt to measure calculus or precalculus (see http://www.actstudent.org/testprep/descriptions/mathcontent.html and http://tea.texas.gov/student.assessment/taks/) may account at least in part for this lack of ISHS impact.

This study provides an example of replicating studies in multiple contexts, a need that is particularly important if research findings are to play a role in guiding education policy. Replication is essential to science, and increased attention is being paid to the need for more replications in education research (Ionnidis, 2014; Makel & Plucker, 2015). Using Schmidt's (2009) replication nomenclature, the Texas study is essentially a direct replication of the North Carolina study. The purpose of running the replication was to observe the generality of ISHS outcomes with a different population of students and schools in different state contexts. During most of the time the students in our Grade 12 sample were in high school, Texas was requiring *all* high school students to complete 4 mathematics courses and 4 science courses for graduation,

a requirement that could be expected to reduce differences between the ISHS and comparison school samples in terms of number of math and science courses taken, taking chemistry, taking physics, and so on. This Texas policy, subsequently revoked in 2013, may account for the fact that students in Texas ISHSs (called T-STEM schools) were not more likely than their peers in comparison schools to have taken chemistry or physics. Such differences in ISHS impact on coursetaking in the two states underscore the importance of taking the broader state context into account when conducting research on nontraditional kinds of schools and when deriving implications for education policy.

A limitation of this study is that the design does not support unequivocal claims for the causal impact for ISHSs. Even though our analytic model controlled for early algebra and for prior mathematics achievement in grade 8 as well as a host of student- and school-level background variables, students choosing to attend ISHSs likely vary from their peers in terms of student and family characteristics that could support interest and achievement in STEM. As our research continues, we will be following samples of ISHS and comparison school students surveyed in grade 9 through their senior year of high school, using propensity score matching to identify students in comparison schools with the same level of STEM interest, prior achievement, and aspirations upon high school entrance, thus allowing for a less ambiguous evaluation of the causal impact of ISHSs. In the interim, from a pragmatic point of view, it appears that middle school students from groups under-represented in STEM, particularly African American, Hispanic and/or female students who have an interest in these disciplines, would do well to consider applying to attend an inclusive STEM-focused high school.

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