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Would a STEM School 'by any Other Name Smell as Sweet'?

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Abstract

The purpose of the present study was to understand how students' math scores change on Texas Assessment of Knowledge and Skills (TAKS) after their schools changed into specialized, inclusive STEM high schools. The sample was selected from five schools in the state of Texas and included 142 students who could be tracked from 7^{th} to 11^{th} grade (2007-2011). The longitudinal data were obtained from the database at the Texas Education Agency (TEA). Paired t-tests by applying Wald Test of Parameter Constrained in Mplus 7 were computed, and the 95% CIs were interpreted to determine how students' math scores on Texas Assessment of Knowledge and Skills (TAKS) changed. Results showed students' achievement during their STEM school experiences had a statistically significant increase ($p<0.05$; $d=0.64$) from 10^{th} to 11^{th} grade. When considering longitudinal change, there was a statistically significant difference in the growth rates favoring STEM school participation ($p<0.05$, $d=0.34$), and both genders experienced practically important changes (Male, $d=0.30$; Female, $d=0.44$). The changes that occurred as schools earned STEM designation seemed to have a positive impact longitudinally. However, it is important to monitor schools to determine if the improvements are durable.

Key words: STEM, Inclusive STEM schools, TAKS, T-STEM academies

Introduction

Science, technology, engineering, and mathematics (STEM) education is critical for today's economy in the United States (U.S.) and abroad. Historically, mathematics and science have been perceived as the disciplines for only talented or gifted students (Stotts, 2011). However, today's economy requires every individual to be educated in STEM disciplines (Erdogan, Corlu, & Capraro, 2013; Young, House, Wang, Singleton, SRI International, & Klopfestein, 2011). STEM education for every citizen is also important to facilitate their personal and societal decisions related to health, environment, and technology in the 21^{st} century (National Research Council [NRC], 2011). To provide such opportunities for each individual in our society, the U.S. needs STEM schools that every student can attend without impediment. In response, specialized STEM school initiatives (Thomas & Williams, 2009) have grown, especially after the report *Rising Above the Gathering Storm* (National Academy of Sciences, 2005). Specialized STEM schools are a candidate to be the nation's best resource for building a STEM workforce.

The idea of specialized STEM schools is not new. The origins of STEM schools trace back to the early 20^{th} century. The need for a talented workforce has led people to establish such institutions so that the nations' economic growth could be guaranteed. The current incarnation of STEM schools is not only intended for students who are interested and talented in STEM disciplines, although there are STEM schools established for only those types of students. The National Research Council (2011) classified STEM schools under three categories: (1) selective STEM schools, (2) inclusive STEM schools, and (3) schools with STEM-focused career and technical education. These three types of schools have slight differences such as in how they select students. However, all three types of schools offer their students a distinguished curriculum and opportunities for research and inquiry with expert teachers and advanced laboratories. In addition, their main aim is to prepare students to obtain STEM degrees in college and pursue a STEM career (NRC, 2011). Despite the long history, we understand little about the contributions of STEM designated schools on student achievements.

The state of Texas has one of the largest inclusive STEM school initiatives in the U.S. The T-STEM initiative started in 2006 and is steadily expanding its scope. As of 2013, there were 65 T-STEM academies (26 campuses for grade 9-12 and 39 campuses for grade 6-12) serving approximately 35,000 students. The T-STEM initiative

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divided the state into 7 regions and each region incorporated a T-STEM center, which was designed to provide technical assistance to the T-STEM academies. These centers supported over 2,800 teachers in specialized areas of concentration (Texas Education Agency, 2013). The distinguishing characteristic of T-STEM academies was the "STEM blueprint" that guided schools in the transition to becoming a STEM school (Avery, Chambliss, Pruiett, & Stotts, 2010). The blueprint clearly explained the guiding principles of T-STEM academies, such as a challenging curriculum, practices related to the daily life, a wide range of STEM coursework, and learning opportunities to meet every student's needs. The blueprint also indicated that T-STEM academies cannot be selective at the time of enrollment but at least 50% of students they accept have to be economically disadvantaged and at least 50% of students enrolled have to come from historically underrepresented populations (i.e., female, diverse, and disabled; Avery et al., 2010; Young et al., 2011). Texas was unique in that it developed a systematic plan for T-STEM schools along with the requirements and expectations.

In the present study, we analyzed high-stakes tests (i.e., Texas Assessment of Knowledge and Skills [TAKS]) results for students who attended T-STEM schools. The sample was drawn from the schools designated to become T-STEM academies in the 2008-09 academic year. This longitudinal study began when students were attending non-STEM schools and followed them through their 11th grade exit testing from a T-STEM designated school. Therefore, students had attended traditional schools and later began to attend specialized T-STEM schools. In particular, our research questions were:

1) What is the change of students' mathematics scores on TAKS between 7th and 8th grades before their schools transition to T-STEM schools? What is the change of students' mathematics scores on TAKS between 10th and 11th grades after their schools became T-STEM schools?
2) Does students' 7th to 8thgrade mathematics growth rate differ as compared to their 10th to11th grade growth rate?
3) How do male and female mathematics performances change from 2008 to 2011?

The Nexus of Achievement and STEM Schools

TAKS is a standardized high-stakes test administered by the Texas Education Agency (TEA) and a commonly used indicator to measure the success of Texas schools at all levels (TEA, 2014). Although the Texas accountability system using this metric has identified T-STEM academies as performing above the state average (Young et al.), T-STEM schools still follow their students' progress closely to make sure that they meet the standards. T-STEM academies put special emphasis on students' performance on TAKS because it is important for students to become academically talented and for T-STEM schools themselves to attract prospective students. Therefore, in this study students' TAKS scores on mathematics were used to evaluate success of school reform with STEM designation.

School Reform with STEM Designation

Educational reforms in schools have aided the U.S. economy since 18th century, especially during national crises. Educational reforms started by Benjamin Franklin continued with major changes in the educational system of the U.S., such as The Smith-Hughes Act of 1917 (Lunenburg & Ornstein, 1996; Parker, 1993). In response to international advancements, such as the launch of Sputnik, the federal government passed the National Defense Education Act (National Defense Education Act of 1958). Affected by the Civil Rights movement in the 1960s, the federal government passed the Elementary and Secondary Education Act (ESEA; Elementary and Secondary Education Act of 1965). In response to the *A Nation at Risk* report, the Educate America Act was passed (Educate America Act of 1994). The next move by the federal government was the No Child Left Behind Act, which was basically the reauthorization of the ESEA (No Child Left Behind Act of 2001). Educational reforms made by the federal government are likely to continue as the demands of society change.

Changing societal demands caused policymakers to think about and act on educational reforms. These reasons include but are not limited to (a) providing equity in education; (b) establishing vocational education; (c) advancing mathematics, science, and language art instructions; (d) creating an optional national curriculum; (e) setting high standards; and (f) creating accountability systems (Stotts, 2011). Among all these reasons, educational reforms almost always involved mathematics and science. Educational reforms in mathematics have shifted back and forth between traditional teaching of theoretical mathematics and progressive teaching of practical mathematics (Stotts, 2011). Educational reforms in science have always focused on making students think and act as scientists and connecting science to the real world (Ravitch, 1995; Seymour & Hewitt, 1997). The policymakers' reasons for initiating educational reforms resulted in changes that appeared strikingly familiar to U.S. stakeholders.

The final educational reform that caused the STEM education initiative was the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES; America COMPETES Act of 2007). This act aimed to enhance innovation in science and technology in the U.S. because science and technology are the key disciplines needed to be competitive among the global community in the 21st century (Corlu, Capraro, & Capraro, 2014). However, achieving the goals of such educational reforms has always been difficult.

Changes Due to STEM Designation

Only three studies have examined transitional STEM schools. Of these studies, one reported quantitative findings, one reported an aggregated synthesis, and one reported qualitative findings (Gourgey, Asiabanpour, Crawford, Grasso, & Herbert, 2009; Stotts, 2011; Young et al., 2011). The results were generally positive but none of the results were large. In two instances, the phenomenon of STEM schools was so new, the data was scarce and there was little in the way longitudinal robustness. Only one study reported results that were not academic in nature. There is too little information for determining the impact of transitioning to a STEM school.

At least marginally improved academic performance was reported in all three studies. In a matched study design there was a difference in academic performance favoring students in T-STEM academies, but the effect sizes were small (0.12 to 0.17) (Young et al., 2011). Further, 9th graders in T-STEM academies performed better in mathematics (Gourgey et al., 2009; Young et al., 2011), and 10th graders in T-STEM academies performed better in mathematics and science than their counterparts in the comparison schools. T-STEM Academies exhibited other important academic outcomes as well. For example, students in grade 9 were 1.8 times more likely to meet the benchmarks of TAKS reading and mathematics, and 10th grade students were 1.5 times more likely to meet benchmarks of TAKS reading, mathematics, science, and social science than their counterparts. When considering subpopulations, students from a low socio-economic background performed slightly better on mathematics compared to the previous year. Additionally, on average, Hispanic students demonstrated higher mathematics scores then previously demonstrated. However, a slight decrease was observed for African American and White students (Gourgey et al., 2009). Across the two studies, achievement was marginally improved, and in only one case was there a large improvement, and that was in the case of Hispanic students.

The use of school variables can provide some degree of understanding of the importance of transitioning to a STEM school. Variables such as students pursuing a college education, female representation in STEM courses, student confidence in their STEM success, and school rating were used. Students in a STEM school were more interested in pursuing a college education, and this result was not limited to STEM majors in college. There was a greater level of enfranchisement and enrollment of girls in taking advanced STEM courses (i.e., Advanced Placement Math and Science). Students' confidence to be successful in STEM courses increased as well as their risk tolerance. A school that was *Academically Unacceptable* became *Academically Acceptable* after being a STEM school for two years, a change that was attributable to increased achievement scores on high-stake tests. The higher achievement was also accompanied by an increase in post-secondary matriculation than had been reported historically (Stotts, 2011). While the variables of interest changed in a positive direction, it is important to determine what the prior performance was and the degree to which performance had changed.

Method

Data Sources

The sample consisted of 4 years of TAKS mathematics data for 142 (62 female) students attending five schools in Texas. The first measurement for the sample occurred when the students were 7th graders in 2007, and the other three repeated measurements subsequently occurred in 2008, 2010, and 2011. Because the same students were measured, the last measurement occurred in 2011 when they were 11th graders.

We purposefully selected the schools that became T-STEM academies in the 2008-09 academic year to be able to observe the growth differences of the students before and after their schools earned T-STEM designation. There were a total of 17 schools that became T-STEM academies in the 2008-09 academic year. While ten of these 17 schools served students in grades 6 through 12, the remaining seven schools only served students in grades 9 through 12; therefore, these seven schools were eliminated. Of the remaining ten schools, five schools were lost to missing data across the 5 year study. While students and not schools were the level of interest, the two were inextricably linked. Students who did not have a TAKS score in any one of the four measurement years were lost to the study. TAKS data were missing for one of three reasons: (1) leaving the T-STEM school, (2) transferring into another T-STEM school or other school, and (3) dropping out of school. Our baseline estimate of performance was when schools the students were attending were not T-STEM academies for the first two measurements in 2007 and 2008. The two subsequent measurements in 2010 and 2011 (when students were in 10^{th} and 11^{th} grades, respectively) were assessed after the schools had been a T-STEM academy for one year, 2008-09. We did not consider the academic year 2008-09 (2009-test scores) performance because it was the year the school, teachers, and students were undergoing the transformation. During the transformation year, teachers might still have been relying on familiar strategies, techniques, and materials; and administrators were still learning what to look for and how to facilitate the T-STEM Academy model.

Data Analyses

Several decisions were made about how the data would be used. The 2008-2009 academic year represented the year in which the change occurred. It functioned as the inflection point in the data analyses or as a point symbolizing a regression discontinuity (Shadish, Cook, & Campbell, 2002). Missing data were expected because the data were longitudinal. We first examined the missing data for characteristics of patterns. Once we determined that missing data were missing completely at random, we used the multiple imputation strategy (Rubin, 1987) by imputing 20 data sets. When more than 40% of the data were missing for any school, it was lost to the study. We used Mplus version 7 (Muthén & Muthén, 1998-2012) to conduct the analyses. Maximum likelihood restricted (MLR) was used as our estimation method. MLR is a robust estimation technique which disregards the assumption of normality (Muthén & Muthén, 1998-2012). Paired *t*-tests by applying Wald Test of Parameter Constrained were used to examine differences between growth rates of 7^{th}-8^{th} and 10^{th}-11^{th} grade performances for all students. We also examined the growth rate differences for males and females separately.

Two new variables were created by subtracting scores of 7^{th} grade from 8^{th} grade, and scores of 10^{th} grade from 11^{th} grade. Then, a paired *t*-test by applying Wald Test of Parameter Constrained was used on these two new difference (growth) variables by using 20 imputed data sets. The 95% Confidence Intervals (CI) were computed for means of 2007, 2008, 2010, and 2011 measurements of TAKS mathematics scores and for the differences, which were used in the paired *t*-tests. The 95% Confidence Intervals (CI) were also computed for the growth differences within female and male subpopulations. The reason for choosing to report CIs was because the APA Task Force on Statistical Inference (Wilkinson & the APA Task Force on Statistical Inference, 1999) strongly recommended the reporting of effect sizes and CIs. Therefore, CIs and Cohen's standardized effect estimates were computed (cf, Navruz, & Delen, 2014; Thompson, 2007).

Results

What is the change of students' mathematics scores on TAKS between 7^{th} and 8^{th} grades before their schools transition to T-STEM schools? What is the change of students' mathematics scores on TAKS between 10^{th} and 11^{th} grades after their schools became T-STEM schools?

In order to see the trend of the means for TAKS mathematics scores in four years, 2007, 2008, 2010, and 2011, means and corresponding 95% CIs for means were drawn on Figure 1.

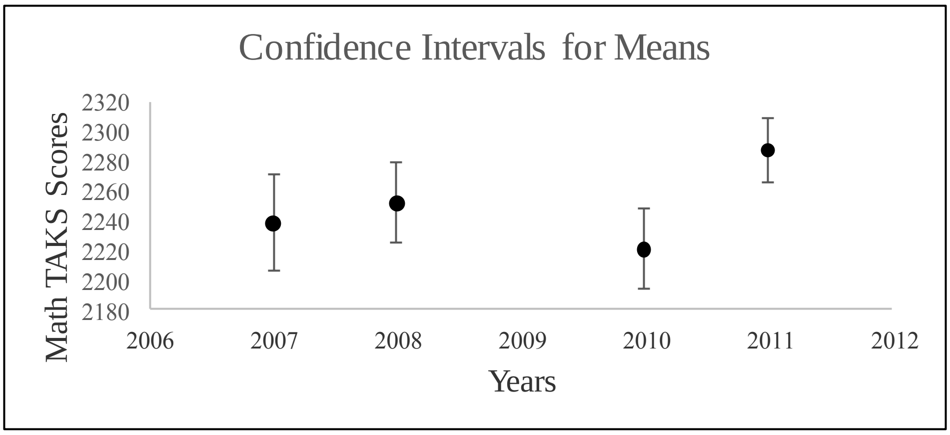

Figure 1. Dots show the means for the TAKS mathematics scores, and 95% CIs for means were shown.

Based on the mean estimates shown in Figure 1, there is an increase from grades 7 to 8 and grades 10 to 11. Notice the slope for 2007-2008 was positive but closer to zero than to 1, and 2010-2011 was greater than 1. Figure 2 shows the mean difference in 95% CIs. Confidence intervals provide information about the precision of the point estimate and spread of the data (Capraro, & Capraro, 2003; Thompson, 2006). In addition, CIs provide information about the statistical significance (Cumming & Finch, 2005). In this case (Figure 2), the 2 whiskers do not overlap by 50%; therefore, there is a statistically significant difference in performance at least at the .05 level (Capraro, 2004).

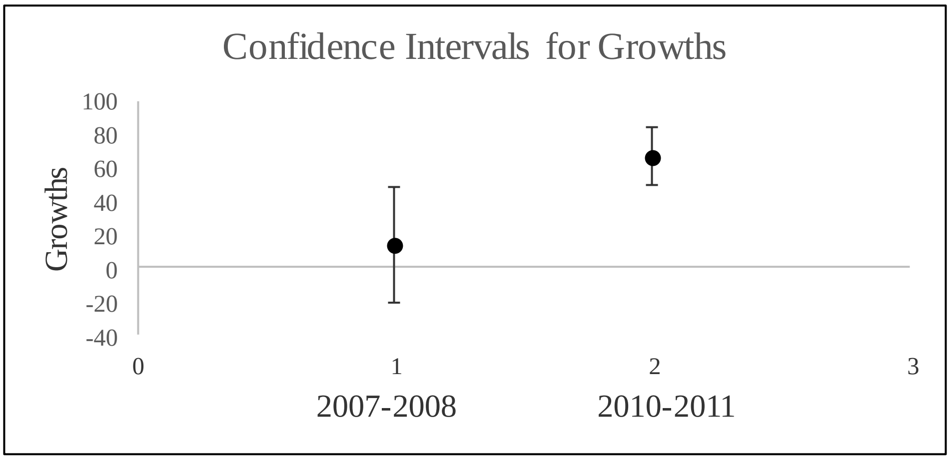

Figure 2. The first (1) 95% CI is for the mean of difference between scores in grades 7 to 8, and the second (2) 95% CI for the mean difference between scores in grades 10 to 11.

The mean differences were tested separately to determine whether or not they were statistically significantly different than 0. The mean difference between grades 7 and 8 was not statistically significantly different from 0 at .05 significance level (t (141) = .293, p= .769). The second mean difference for grades 10 and 11 was statistically significantly different from 0 at .05 significance level (t (141) = 3.572, p = .001).

Does students' 7^{th} to 8^{th}grade mathematics growth rate differ as compared to their 10^{th} to11^{th} grade growth rate?

In the paired *t*-test, the mean difference scores, which were shown in Figure 2, were tested whether or not they were statistically significantly different from each other. In Mplus, a paired *t*-test can be conducted by testing a model fit to determine whether the difference of two means is equal to 0. Because we are testing the model in Mplus, the Wald Test of Parameter Constrained, which follows Chi Square distribution (Engle, 1984), was used. In our model, in order to test if the means of the differences were equal, the two parameters' estimates for the means were constrained to be equal. Based on the Wald test statistics, 4.639, with 1 degree of freedom produced a *p*-value smaller than 0.05, which meant we rejected the null for the equality of the growths between 7-8 and 10-11.

How do male and female mathematics performances change from 2008 to 2011?

In order to determine males' and females' growth rate pattern, 95% CIs for means of both groups were drawn. Figure 3 shows the differences of these growth rate differences with 95% CIs for both males and females.

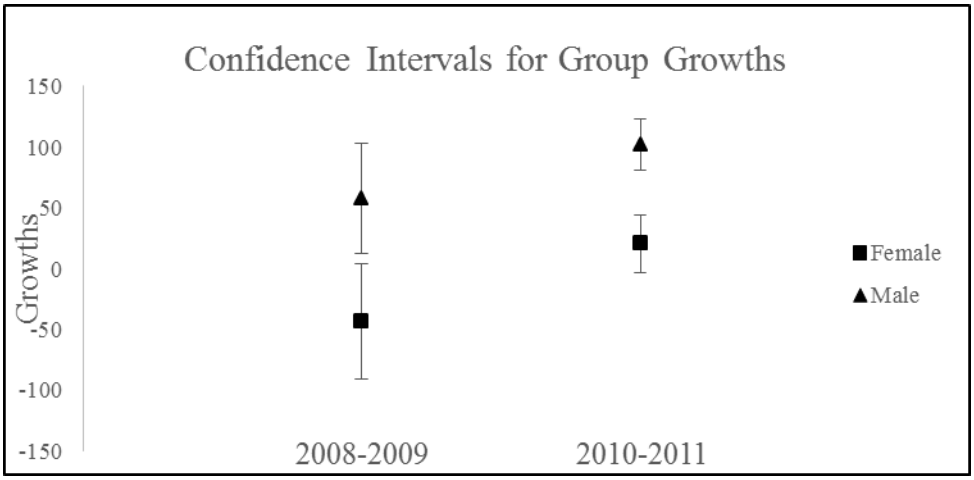

Figure 3. Both males' and females' 95% CIs are for the mean of difference between scores from grades 7 to 8 (2008-2009) and the 95% CIs for the mean difference between scores from grades 10 to 11 (2010-2011).

The mean differences for males from 7th to 8th grade showed a statistically significant increase ($p < 0.05$, d=0.49) while the mean of female scores yielded a statistically significant decrease (p< 0.05, d=-0.22). However, between 10th and 11th grades, both groups showed a statistically significant increase (Male, p< 0.05, d=1.06; Female, p< 0.05, d=0.21) on their TAKS mathematics scale scores. Means and SDs were provided in Table 1 and Cohen's *d* effect sizes were provided in Table 2. Figure 3 showed the 95% CIs for both male and female mathematics score growth when the students were in middle and high schools. The growth of male students' mathematics scores was statistically significantly higher than female students' scores in both middle and high schools. The growth rate difference for females (d=0.44) was slightly higher than males (d=0.30). For male students, the growth rate was positive in both cases.

Table 1. Mean, SDs, and 95% CIs

Grade	Male		Female		Overall	
	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI
7th	2238 (199)	[2194, 2281]	2238 (199)	[2189, 2288]	2238 (200)	[2205, 2271]
8th	2295 (158)	[2261, 2330]	2195 (150)	[2158, 2232]	2252 (164)	[2225, 2278]
10th	2211 (165)	[2175, 2248]	2232 (163)	[2191, 2273]	2220 (165)	[2193, 2247]
11th	2314 (128)	[2286, 2342]	2252 (127)	[2221, 2284]	2281 (132)	[2265, 2308]
8th-7th	57 (207)	[12, 103]	-43 (192)	[-91, -3]	14 (209)	[-21, 48]
11th-10th	102 (96)	[81, 123]	20 (95)	[3, 44]	67 (105)	[49, 84]

Table 2. Cohen's d Effect Sizes

Growths	Male	Female	Overall
	d	*d*	*d*
8th-7th	0.49	-0.22	0.07
11th-10th	1.06	0.21	0.64
(11th-10th)-(8th-7th)	0.30	0.44	0.34

Discussion

The purpose of the present study is to examine how students' mathematics growth on the TAKS changed after their schools turned into specialized inclusive STEM schools. To the best of our knowledge, this study is unique in terms of its sampling procedure compared to previous studies regarding STEM schools' performance. Previous research, although not experimental, has mostly compared two groups of students by applying either the propensity or exact matching procedure (Young et al., 2011). However, in the present study, rather than comparing two groups of students in terms of their school types (STEM and non-STEM), we observed the same students' mathematics growth on TAKS by comparing students' mathematics growth when their schools were non-STEM schools with their mathematics growth after their schools turned into specialized STEM schools.

To refer back to the title, *Would a STEM School 'by any Other Name Smell as Sweet'?*, Juliet in Shakespeare's *Romeo and Juliet* argues that the names of things do not matter; only what things are matters. The study indicates that regardless of what we call the schools, what they are is what matters. Looking at the results, findings indicated students' overall mathematics TAKS score growth between the 7^{th} and 8^{th} grade was not statistically significant. This might be explained by the fact that mathematics teachers in most traditional public K-12 schools focused on a teaching methodology aligned to a theoretical perspective of algorithmic mastery (Stotts, 2011). In order for students to experience positive growth in mathematics, they need to develop both a conceptual and a procedural understanding of mathematical concepts (Ashlock, 2005) simultaneously without scaffolding. STEM practices (i.e., Project Based Learning (PBL) and Problem Based Learning) in mathematics classrooms might be effective instructional methods for helping students learn mathematics meaningfully by simultaneously developing their conceptual and procedural understanding with necessary scaffolds situated in applied learning that is part of their STEM PBL lessons.

Another finding revealed that after the transition year for when students' schools turned into specialized STEM schools, their mathematics growth on TAKS between 10^{th} and 11^{th} grade was statistically significant. In other words, students' 11^{th} grade mathematics TAKS scores were statistically significantly higher than their 10^{th} grade mathematics TAKS scores with 0.64 Cohen's *d* effect size. This result is congruent with our assumption that the support, STEM School Vision, and professional development in specialized STEM instruction for teachers delivered by T-STEM centers were effective and appropriate; thus, their students' mathematics growth showed an increased pattern from 10^{th} to 11^{th} grade as opposed to their growth from 7^{th} to 8^{th} grade. It appears that the STEM high school model seems to be paying off.

The results showed a marked decrease in student performance in 2010 as compared to 2008. In 2009, the transition year, we expected performance to reflect some of what teachers had been doing prior to their school becoming a STEM school and some of what the teachers were learning they needed to do in a STEM school. The minor change in 2010 seems to indicate that the change in school focus impacted scores for the years 2009 and 2010. In 2011, after being in a STEM school for three years, students' scores exceeded their previous highest mean. Most importantly, the steepness (slope) of the gain far exceeded the steepness (slope) of the benchmark years. This seems to indicate that both the rate of learning and mean score increased beyond what would have been normally predicted from the first two time points. Students regained lost achievement in the transition years and at a minimum attained the same level of achievement had they continued to grow in achievement in a linear pattern across all the years.

It is important to consider students' growth rate changes as their school transitions to being a STEM school. Change in itself can be problematic; while the destination can lead to greater academic achievement, the change can also be the factor responsible for lower achievement during the transition period. To provide greater insights into the value of a school transitioning to being a STEM school, we examined the importance of the gains before and after the transition. The growth rate differences indicated a statistically significant difference and an increased rate of learning. Students seemed to be performing better after participating in a STEM school by the time they took their exit tests.

Students' mathematics growth rate after the students' schools turned into STEM schools was statistically significantly higher than their mathematics growth rate before their schools turned into STEM schools, with 0.34 Cohen's *d* effect size. In terms of comparing STEM and non-STEM schools, this finding is parallel with the findings of Gourgey, et al. (2009) and Young et al. (2011), which showed that 9^{th} and 10^{th} graders in STEM schools performed better than their counterparts in non-STEM schools. This increase in students' mathematics growth might be explained by T-STEM schools providing a challenging curriculum, a focus on educational practices related to real life, a greater variety of STEM courses, and new learning opportunities to meet students' needs (Avery et al., 2010; Young et al., 2011). These features of T-STEM schools may lead students to have more engagement with science and mathematics. Further, being exposed to a STEM culture may increase their interest in science and mathematics.

There is a national deficit of women entering STEM fields. Our findings indicated differentiation in gender. Male students showed greater average achievement than female students in both middle and high school. However, female growth showed a marked increase from middle to high schools. Males had positive growth; the slope was not as steep as the females' slope. Indeed, female growth rate difference was slightly higher than male growth rate difference. This might be due to the T-STEM schools' designation that emphasizes underrepresented subpopulations (ethnic minority, female, and low-SES) to decrease the mathematics achievement gap (NRC, 2011). One of the main aims of the STEM education initiative (America Competes Act of 2007) is to decrease the achievement gap between student demographic groups (Lynch, Behrend, Burton, & Means, 2013). The obtained effects might be explained by the fact that female students developed a more positive disposition towards STEM instruction when presented with the opportunities. It cannot be overlooked that the female students had a negative growth rate before being in a STEM school and a positive gain by the time they took the exit exam. The STEM pedagogical strategies that include group work and active engagement (e.g., PBL, Inquiry Based Learning, and Problem Based Learning), hands-on activities, connecting topics with real life applications, and increased cooperative and collaborative learning opportunities could have provided the framework for greater engagement (Myers & Fouts, 1992; Oakes, 1990). For these particular students they experienced enhanced performance as indicated by test score.

This study has several limitations. The first one is we had only had 142 students longitudinally to conduct the study. Our results would have been more robust if we had more data. However, student transfers between schools, dropouts, and moving out of state drastically reduced our sample size. Another condition limiting our sample size was that of missing data. Across the years, a student who for some reason does not take the test is lost to the study. Future study with both student and school level data that compares STEM and non-STEM schools would shed more light on the discussion of whether STEM schools fulfill the promise of greater student achievement in STEM courses.

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