LONGITUDINAL EXAMINATION OF TEXAS SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) ACADEMIES

A Dissertation

by

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ABSTRACT

The research generated from this dissertation study focuses on the effectiveness of Science, Technology, Engineering, and Mathematics (STEM) schools from different perspectives. The substantial amount of investment given to STEM schools required the investigation of the influence of STEM schools on students' academic achievement. The research from the first study in this dissertation focuses on the effectiveness of Texas STEM schools (T-STEM academies) from a broader perspective by comparing T-STEM academies in different regions. The second study focuses on the influence of STEM practices on students' academic achievement by comparing T-STEM academies to traditional high schools longitudinally. The third study focuses on the effectiveness of T-STEM charter schools in comparison to non-TSTEM charter schools. Lastly, the fourth study highlights the importance of the duration of implementation by focusing on the effect of STEM designation in middle school and the years of designation as a T-STEM academy.

Results from the first study showed that T-STEM academies located in different regions did not differ in terms of students' mathematics achievement longitudinally. Schools in regions were supported by Regional Education Service Centers (ESC) in terms of assistance on instruction. According to the findings of the first study, students' mathematics achievement in T-STEM academies in different ESCs was not statistically significantly different. In the second study, students' mathematics, reading, and science achievement did not differ longitudinally according to their schools: T-STEM or traditional high schools. However Asian, and at-risk students in T-STEM academies

showed better mathematics and reading growth. Students' mathematics and reading scores, who were in T-STEM charter schools and non-T-STEM charter schools, differed over time. Hispanic students in T-STEM charter schools showed higher positive growth over time than Hispanic students in non-T-STEM charter schools. Lastly, students who attended T-STEM academies in middle school had higher Algebra I and Algebra II scores in high school than their peers, who enrolled in T-STEM academies in ninth grade. In addition, if a T-STEM academy had a designation as an academy for at least four years, students in these academies had higher scores than their counterparts.

Overall, results from this dissertation study showed that T-STEM academies partially fulfill their promise. Hispanic and economically disadvantaged students in T-STEM academies showed better growth than their counterparts. The major participants of T-STEM academies were Hispanic and economically disadvantaged students. The results from the four studies showed that instruction in T-STEM academies was beneficial to one group of minority (i.e., Hispanic) students as well as economically disadvantaged students. Moreover, this dissertation study highlights the importance of implementation in schools. Students who are taught using STEM practices in middle grades are highly likely to reach desired results. In addition, the duration of the designation as a STEM school plays an important role on students' academic achievement.

DEDICATION

To my parents for their love and support over the years

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NOMENCLATURE

AP	Advanced Placement
CI	Confidence Interval
ED	Economically Disadvantaged
ESC	Education Service Centers
FML	Full Maximum Likelihood
GPA	Grade Point Average
HLM	Hierarchical Linear Modeling
JCR-SSCI	Journal Citation Reports Social Sciences Citation Index
LEP	Limited English Proficiency
MCAR	Missing Completely At Random
MI	Multiple Imputation
NCLB	No Child Left Behind
NED	Not Economically Disadvantaged
NRC	National Research Council
NSB	National Science Board
PBL	Project Based Learning
PCAST	President's Council of Advisors on the Science and Technology
REML	Restricted Maximum Likelihood
SAT	Scholastic Aptitude Test
SES	Socio-Economic Status

SJR	SCImago Journal Rank
SNIP	Source Normalized Impact per Paper
SSCI	Social Sciences Citation Index
STAAR	State of Texas Assessments of Academic Readiness
STEM	Science, Technology, Engineering, and Mathematics
STEM/ECHS	Science, Technology, Engineering, and Mathematics/Early College High School
TAC	Texas Administrative Code
TAKS	Texas Assessment Knowledge and Skills
TEA	Texas Education Agency
TEC	Texas Education Code
THS	Traditional High Schools
THSP	Texas High School Project
T-STEM	Texas STEM Academies
T-STEM ADB	T-STEM Academy Design Blueprint
WWW	What Works Clearinghouse

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CHAPTER I

INTRODUCTION

To maintain successful leadership status, progress, and prosperity, the United

States (U.S.), needs students interested in science, technology, engineering, and

mathematics (STEM) and STEM graduates. In the future, these STEM graduates will

become workers who drive the nation's innovation and generate new ideas (President's

Council of Advisors on Science and Technology, 2010; U.S. Department of Commerce

Economics and Statistics Administration, 2011). Maintaining large numbers of

individuals pursuing a STEM degree is not only necessary for the nation's prosperity, it

is also helpful for an individual's own future. STEM-related jobs have become more

desirable and have been growing in numbers and types over the past ten years (U.S.

Department of Commerce Economics and Statistics Administration, 2011). The

increasing job market is not the only reason that shows the importance of STEM; STEM

occupations also have a great influence on the economic growth and stability of the

nation and are among the highest paying jobs (Thomasian, 2011; U.S. Department of

Commerce Economics and Statistics Administration, 2011). Ultimately, to obtain more

STEM workers, a greater number of STEM graduates are needed.

To increase the number of STEM inclined individuals and STEM graduates,

additional recommendations were proposed by the President's Council of Advisors on

the Science and Technology (PCAST) and the National Research Council (NRC). These

recommendations included (a) increasing the number of STEM degrees and career

dedicated students, (b) including underrepresented groups in the STEM workforce and

enhancing the number of STEM workers, (c) making students STEM literate (NRC, 2011a), (d) creating common standards for mathematics and science, (e) preparing 100,000 STEM teachers, (f) acknowledging and supporting the top 5% of the nation's STEM teachers, (g) embedding more technology into education, (h) increasing students' extracurricular experiences, (i) assuring strong and strategic national leadership, and (j) designing 1,000 new STEM schools including elementary, middle, and high schools over the next decade (PCAST, 2010). The purpose of these STEM schools was to carry out many of these recommendations from the NRC in formal learning environments.

Every year, the number of specialized STEM schools has been increasing as demonstrated by the designation of different types of STEM schools. There are four basic types of STEM schools: (1) selective STEM schools, (2) inclusive STEM schools, (3) STEM-focused career and technical education schools, and (4) STEM in comprehensive schools (NRC, 2011a). In 2010, the total number of selective and inclusive STEM schools was 273 (Rogers-Chapman, 2013) with 33 of them in Texas and nearby states. As of the 2010-2011 academic year, the number of STEM schools in Texas increased to 46 and this number has been growing rapidly in Texas, rising to 65 in 2012-2013 (Educate Texas, 2013a).

The funds allocated to Texas STEM (T-STEM) academies are substantial. Investments in these schools started in 2006 and $54.4 million was set aside for funding just T-STEM academies. Funding for T-STEM academies only in the 2012-2013 academic year was $1,730,000. These schools served over 35,000 students and this investment has been continuous in hopes of increasing the mathematics and science

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achievement of their students while enhancing the number of students who pursue STEM degrees and careers. Therefore, an investigation of these STEM schools was needed. The intent of the research conducted during this dissertation study was to focus on inclusive STEM schools in the state of Texas. Specifically, T-STEM academy students' academic achievement was investigated from multiple aspects.

Statement of the Problem

The research conducted during this dissertation study focused on T-STEM academy students' academic achievement compared to achievement in other types of schools because the number of studies focusing on students' academic achievement and growth has been limited. It is important to understand the growth and success of STEM schools because of the above-mentioned reasons. Furthermore, the investment that has been contributed so far has been remarkable and should not be ignored. Additionally, a longitudinal analysis of the performance of students in these schools was another gap in the literature. Moreover, the Educational Service Centers that are responsible for providing any educational support to T-STEM academies were not investigated deeply to determine whether they successfully pursue their goal. In addition, no prior research studies examined the effectiveness of STEM schools in early grades. To fill these gaps, the research conducted during this dissertation study resulted in four articles focusing on longitudinal examination of achievement levels of students in T-STEM academies and their traditional high school counterparts, longitudinal examination of achievement levels of students in T-STEM charter academies and their charter school counterparts, an

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analysis of T-STEM academy students' early STEM experiences, and comparison of T-STEM academies by educational service centers.

Purpose of the Study

The purpose of the research conducted during this dissertation study was to examine the effectiveness of T-STEM academies. The definition of effectiveness in this study was measured by student achievement on the state standardized test, the Texas Assessment Knowledge and Skills (TAKS) and the State of Texas Assessments of Academic Readiness (STAAR). These scores were the measure of students' academic achievement. The four articles heavily focused on T-STEM academies. The first article's purpose was to determine the performance of T-STEM academies in different regions to determine whether the academic achievement differs across Education Service Centers. The second articles' purpose was to reveal whether T-STEM academy students' academic achievement in mathematics, science, and reading subjects differed from their non-T-STEM counterparts, specifically traditional high school students, over a three year period. The third article's purpose was to examine the reason behind charter schools becoming T-STEM academies by investigating the difference between student achievement (i.e., mathematics, science, and reading) in T-STEM charter schools and non-T-STEM charter schools. In the fourth article, the influences of attending a T-STEM academy starting in middle school and the effect of years attending a T-STEM academy were analyzed. More specifically, I examined the difference between the student achievement of those who attended a T-STEM academy beginning in 6th grade and students who attended a T-STEM academy beginning in 9th grade. Thus, the fourth

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article showed whether years in attendance made a difference. The research conducted during this dissertation study contributed to knowledge about the effectiveness of STEM schools and STEM education literature and shed light on pathways for future researchers by filling a gap in the literature.

Literature Review

There should be criteria to identify successful STEM schools. Three criteria were suggested by the National Research Council (2011). The first criterion was students' STEM outcome. In prior studies, students' STEM outcomes were measured by standardized test scores (Oner, Erdogan, Sahin, Capraro, & Capraro, 2013; Oner et al., 2014; SRI International, 2011; Young, House, Wang, Singleton, & Klopfenstein, 2011). Although students' STEM outcomes were used to measure student success in STEM fields, other measures such as motivation, interest, and attitude (e.g., Erdogan, Oner, Cavlazoglu, Capraro, & Capraro, 2013; Erdogan, Oner, Sahin, Capraro, & Capraro, 2014) were also necessary in evaluating students' STEM outcomes (NRC, 2011a). The second criterion was STEM instruction and educational practices applied in schools whether or not they were STEM schools, because any instruction that captures students' interest in STEM fields should be effective (NRC, 2011a). The last criterion was STEM-focused school types because generally STEM schools were seen as the most powerful way to improve STEM education (NRC, 2011a). STEM schools were viewed as one of the successful STEM criteria, therefore, worthy of deep investigation.

Types of STEM Schools

There were four types of STEM schools classified in the report from the NRC (2011a). According to NRC report, the four types were: (1) selective STEM schools, (2) inclusive STEM schools, (3) schools with STEM-focused career and technical education (CTE), and (4) STEM in comprehensive schools. Selective STEM schools selected their students according to criteria that they determine. Inclusive STEM schools were open-admission STEM schools that did not require any criteria. STEM-focused career and technical education schools prepared students for STEM jobs that did not require four-year college degrees. The last type of school included STEM subjects as well as other academic subjects comprehensively. Among these four types of STEM schools, inclusive STEM schools were the most likely schools to be compared with traditional public schools because they were the most similar.

This dissertation study research focused on inclusive STEM schools. T-STEM academies were inclusive STEM schools located in Texas. My investigation was limited to only T-STEM academies. Inclusive STEM schools did not have selection criteria in contrast to selective STEM schools. Thus, these institutions served a more underrepresented group of the broader population of students. Inclusive STEM schools were built upon:

> the dual premises that math and science competencies can be developed; and that students from traditionally underrepresented subpopulations need access to opportunities to develop these competencies to become full participants in areas of economic growth and prosperity. (Young et al., 2011, p. 2)

Thus, inclusive STEM schools encouraged students to improve their knowledge and skills in STEM areas rather than relying on students' prior strong academic achievement or interest in STEM in contrast to selective STEM schools (Young et al., 2011). Some of these students were interested in STEM subjects; however, this was not one of the selection criteria for inclusive STEM schools. STEM schools in the state of Texas serve as outstanding models for inclusive STEM schools (NRC, 2011a). Inclusive schools were both school-within-a-school and stand-alone types of schools.

One kind of inclusive school was school-within-a-school which had a subset of students in a school enrolled in the STEM part of the school (S. Avery, personal communication, January 8, 2014). In this type of school setting, there might be other independent programs running as well as STEM academy programs. This segregated school in a campus selected students interested in STEM fields as well as allowing students to maintain relationships with the non-STEM community on the campus (Tofel-Grehl, 2013).

The second type of inclusive STEM school was stand-alone schools in which all students on a campus or school setting were enrolled in a particular school (S. Avery, personal communication, January 8, 2014). All students in that school were accepted as participants of a STEM academy. These schools provided better results for studies compared to school-within-a-school type STEM schools because of having only STEM students' scores.

The state of Texas authorized its first STEM schools in 2006. STEM schools in the state of Texas (i.e., T-STEM academies) were inclusive STEM schools. Even though

there were two types of STEM schools in Texas, (a) stand-alone and (b) school-within-a-school, this study focused directly on stand-alone T-STEM academies. The reason was because school-within-a-school type T-STEM academy student achievement results also included non-STEM students' results and it was not possible to separate out STEM students' score from non-STEM peers in school-within-a-school type T-STEM academies. Thus, this study only focused on stand-alone T-STEM academies' student achievement and stand-alone T-STEM academies were primarily used in conducting the research for this dissertation study.

Research Questions

1. Do Education Service Centers differ in how they affect T-STEM academies' mathematics achievement over a number of years by gender, ethnicity, and SES?

2. How do T-STEM academy students' test scores longitudinally differ from traditional high school students' test scores on mathematics, science, and reading?

3. How do students from T-STEM charter schools longitudinally differ from students in Texas charter schools by mathematics, science, and reading achievement?

4. How do the scores of students who were exposed to STEM education starting in 6th grade differ from those of their peers who attended T-STEM academies beginning in 9th grade? How does students' academic achievement differ by years of the designation of T-STEM academies (i.e., 3 years or more)?

Journal Selection

For each proposed article manuscript, two potential journals have been selected. The reason for choosing these particular journals was the scope and aim of how each particular journal fit each of the three studies. STEM schools and all related contexts with STEM schools such as STEM education, STEM interest, and STEM career choice were very broad. Because STEM includes four fields, the authors who were cited in this study published their research in different journals related individually to these four subjects. Therefore, I have chosen the following journals where these four subjects were intertwined. During journal selection indexing in the *Social Sciences Citation Index* (SSCI) and impact factor were also considered. Impact factors or *SCImago Journal Rank* (SJR) and *Source Normalized Impact per Paper (SNIP)* were found on the primary web sites; *Scopus database of abstracts and citations for scholarly journal articles* and *Journal Citation Reports Social Sciences Citation Index* (JCR-SSCI). Acceptance rates, review type, and length of manuscript from *Cabell's Directories* were also referenced to choose the journals (see Table 1).

Table 1

Proposed Articles and Journals

Proposed Articles	Proposed Journal #1	Proposed Journal #2
*Article 1: T-STEM Academies' Academic Performance Examination by Education Service Centers: A Longitudinal Study	*Turkish Journal of Education* • Acceptance rate: NA • Impact and ranking: NA • Editor in chief/Associate editors: Orhan Ercan/ Selahiddin Öğülmüş/ Mehmet Tekerek • Publisher: NA • Type of review: Double-Blind Review • Manuscript length: NA	
Article 2: The Investigation of T-STEM Academy Students' Scores: A Longitudinal Comparison with Traditional High Schools	*International Journal of Science and Mathematics Education* • Acceptance rate: 30% • Impact and ranking (SJR/SNIP): 0.759/1.121 • Editor in chief/Associate editors: Huann-shyang Lin/ Larry D. Yore, Hsin-Kai Wu • Publisher: Springer • Type of review: Double-Blind Review • Manuscript length: Max. 30 pages	*School Science and Mathematics* • Acceptance rate: 20% • Impact and ranking (SJR/SNIP): N/A • Editor in chief/Co-editor: Carla C. Johnson/ Shelly Harkness • Publisher: Wiley Blackwell • Type of review: Blind Review • Manuscript length: 21-25 pages

(continued)

Table 1 (continued)

Proposed Articles	Proposed Journal #1	Proposed Journal #2
Article 3: The Effect of T-STEM Designation on Charter Schools: Longitudinal Examination	*Eurasia Journal of Mathematics Science and Technology Education* • Acceptance rate: 16-17% • Impact and ranking (SJR/SNIP): 0.14/1.61 • Editor in chief/Associate editors: Mehmet Fatih Taşar/ Stephen Ritchie • Publisher: Moment Publications • Type of review: Double-Blind Review • Manuscript length: N/A	*International Journal of STEM Education* • Acceptance rate: NA • Impact and ranking (SJR/SNIP): NA • Editor in chief/Associate editor: Yeping Li/ Jeffrey Froyd • Publisher: Springer • Type of review: Double-Blind review • Manuscript length: N/A
Article 4: The Effects Of Stem Middle School On Stem High School Students' Achievement	*Journal of Science Education and Technology* • Acceptance rate: 21-30% • Impact and ranking (SJR/SNIP): 0.737/1.356 • Editor in chief/Co-editor: Karen C. Cohen/ Kent J. Crippen • Publisher: Springer • Type of review: Blind Review • Manuscript length: max. 30 pages	*International Journal of Mathematical Education in Science and Technology* • Acceptance rate: 38% • Impact and ranking (SJR/SNIP): 0.295/0.687 • Editor in chief: M. C. Harrison • Publisher: Taylor & Francis • Type of review: Blind Review • Manuscript length: N/A

Note: SJR= SCImago Journal Rank.
SNIP= Source Normalized Impact per Paper.
N/A= not available.
* Published article

Article 1: T-STEM Academies' Academic Performance Examination by Education

Service Centers: A Longitudinal Study

Regional Education Media Centers were established in 1965 in the state of Texas to distribute educational media and render professional materials (Texas Public School System, 2013). This organization's title and role has changed over time and it is now known since 1967 as Regional Education Service Centers (ESCs). The duties of ESCs were to provide service for instructions, instructional materials, and delivery of these materials to teachers (Floyd, 2007) and ESCs were partner of Texas Education Agency (TEA) since 2006.

School districts and ESCs are connected to each other through partnerships. School districts can function without ESCs' support; however, their quality might be questionable (Jackson, 2004). The general goal of ESCs is to provide " a support system for the schools in their respective areas, especially in disseminating information, providing technological assistance, and training administrators, teachers, and students" (Floyd, 2007, pp. 32-33). Therefore, the main expectation from ESCs would be any instructional assistance for any type of school. For instance, accountability was one of the important issues for schools; thus, ESCs were expected to provide support to improve students' TAKS scores. Another example was the planning of English as Second Language programs by ESCs for schools that had limited English proficient students. ESCs offered training sessions for new teachers or provided technical assistance to districts that had problems.

Since 2006, T-STEM academies have been serving mostly minority and/or economically disadvantaged students (Young et al., 2011). T-STEM academies opened with a goal of increasing the number of students pursuing STEM degree and improving students' mathematics and science achievement. To educate students with this purpose, they had a specific model design and curriculum. Because STEM education required a specific curriculum (Avery, Chambliss, Truiett, & Stotts, 2010), these schools needed special assistance. Due to the purpose of ESCs, they should be very helpful for these particular schools.

ESCs consider the specific needs of a school before providing support (Texas System of Education Service Centers, 2013). Every T-STEM academy might have different needs; therefore, it was worthwhile to determine the influence of ESCs on T-STEM academies. Students' high-stakes test scores in T-STEM academies were used to investigate if there was a difference among T-STEM academies in different ESC Regions. Within the investigation conducted in this study, it was possible to understand whether there were differences among T-STEM academies by achievement over time and, furthermore, if this difference was caused by a particular ESCs' support.

Article 2: The Investigation of T-STEM Academy Students' Scores: A Longitudinal Comparison with Traditional High Schools

The workforce need in the fields of science, technology, engineering, and mathematics has brought with it the need for STEM schools. To answer that need, many states have started to create STEM schools for students at different levels. Texas has created T-STEM academies serving both middle and high school students beginning

with the 2006-07 academic year. Since that time, the number of T-STEM academies has rapidly increased. The primary goals of T-STEM academies are to improve students' science and mathematics achievement in Texas (Avery et al., 2010) and to increase the number of students who will pursue a degree and a career in STEM fields (Educate Texas, 2013b).

While the purpose of creating T-STEM academies was to encourage students' STEM interest and increase student achievement in STEM areas, it is important to examine the effectiveness of these schools to determine whether they actually fulfill their primary goals. When students' schools became T-STEM schools, their mathematics scores increased as compared to those not enrolled in a STEM school (Navruz, Erdogan, Bicer, Capraro, & Capraro, 2014). However, there were no detectable differences in performance for students who were in T-STEM academies and traditional high schools (Bicer, Navruz, Capraro, & Capraro, 2014; Erdogan, 2014). Hispanic STEM students' mathematics (Bicer et al., 2014; Erdogan, 2014), science, and reading achievement (Erdogan, 2014) and White students' academic achievement in general (Erdogan, 2014) was higher than that of the comparison group. T-STEM students who were economically disadvantaged had higher scores than their peers (Erdogan, 2014). These results showed the effectiveness of T-STEM academies impacting on students' academic achievement.

Prior studies about T-STEM academies examined the academic achievement of students for one year. A longitudinal examination of these schools was critical for understanding the growth change. Thus, data from this study provided more detail concerning the progress of students in T-STEM academies for reader. The purpose of the

research that was conducted during this study was to provide a longitudinal examination of T-STEM academy and non T-STEM school students' academic achievement in reading, mathematics, and science from 2010-11 (9th grade) through 2012-13 (11th grade).

Article 3: The Effect of T-STEM Designation on Charter Schools: A Longitudinal Examination

In the U.S. education system, charter schools were one type of school in addition to traditional public schools. In 1995, the creation of charter schools was authorized in Texas with goals of (a) improving student achievement, (b) enhancing the opportunity for learning in a public education system, (c) supporting new learning methods, (d) constituting opportunities for gaining additional teachers to the current system, and (e) creating a new form of accountability (Taylor et al., 2011). Accountability was an important factor for charter schools because if schools did not meet sufficient criteria, they could be discharged from their role as a charter school (Nathan, 1996). Not meeting annual state academic and financial standards is one possible reason to close a charter school (Texas Education Agency, 2014a).

T-STEM academies formed another group of schools in Texas. A T-STEM academy could be a charter School, a district school, or a district charter school. These academies generally started off as a non-STEM academy because the designation required the completion of an application to the Texas Education Agency to earn designation. Earning the T-STEM academy designation usually required meeting additional criteria as explained in the *T-STEM Academy Design Blueprint* (*T-STEM*

ADB) (Avery, 2010).

The number of charter schools that have turned into T-STEM academies has been substantial. In the 2012-2013 academic year, there were 65 T-STEM academies and 37 of them were stand-alone T-STEM academies. 29 out of 65 T-STEM academies were charter schools and 25 of them were stand-alone T-STEM charter schools. If we consider the number of stand-alone T-STEM academies, almost 70% of them were charter schools before receiving their T-STEM designation. It was worthwhile to investigate the effectiveness of T-STEM charter schools.

To attain T-STEM academy designation, a school must apply for it. If they meet certain criteria, they become T-STEM academy eligible. One obvious criteria for becoming a T-STEM academy was to understand and follow the purpose of these academies. Criteria included: (a) improving students' mathematics and science achievement in Texas (Avery, 2010), (b) increasing the number of students who want to study and have a career in STEM fields, (c) empowering teachers through high quality professional development, and (d) promoting school leadership (Educate Texas, 2013b). Other examples of criteria were: (1) targeting at-risk students, (2) requiring no enrollment restrictions, (3) implementing T-STEM Blueprint, and (4) making progress on the Blueprint continuum. To ensure that T-STEM academies follow these criteria, a *T-STEM ADB* was used.

T-STEM academies had their own design called the *T-STEM ADB*. This blueprint's role was to "guide school leaders on planning and implementation of T-STEM academies" (Young et al., 2011, pp. 3). Within the *T-STEM ADB*, there were

benchmarks and rubrics that assessed how T-STEM academies perform on those benchmarks. These benchmarks and rubrics played an important role in the T-STEM Academy model because they allowed reviewers to assess a T-STEM Academy's performance against their benchmarks.

The *T-STEM ADB* had seven benchmarks that have changed over time. The first blueprint was written in 2005 and revised in 2008. The currently available version of the blueprint was written in 2010 (Avery et al., 2010). Blueprint benchmarks include: (a) mission-driven leadership, (b) T-STEM culture, (c) student outreach, recruitment and retention, (d) teacher selection, development and retention, (e) curriculum, instruction and assessment, (f) strategic alliances, and (g) academy advancement and sustainability. The *T-STEM ADB* is currently assessed with a *T-STEM ADB Rubric*. Academies are expected to make progress on each benchmark every year and serve as a role model school for STEM teaching and learning according to the *T-STEM ADB* assessed with a specific rubric (Avery et al., 2010; Educate Texas, 2013b).

The main difference between T-STEM charter schools and non-T-STEM charter schools is the *T-STEM ADB* that aimed to promote a more effective STEM teaching and learning environment than other schools. Therefore, in this study the difference between T-STEM charter and non-T-STEM charter schools' student academic achievement (i.e. mathematics, reading, and science) over three years (2010-11/2011-12/2012-13) was examined.

Article 4: The Effects of STEM Middle School on STEM High School Students'

Achievement

More and more attention has been focused on STEM education yearly. When government officials released the call for the need for STEM graduates (Committee on Science, Engineering, and Public Policy, 2005; Kuenzi, Matthews, & Mangan, 2006; Newcombe et al., 2009) in depth research began focusing on STEM education. The term "STEM pipeline" has been used to refer to entering a STEM related field for students who enter the post-secondary STEM track (Oner & Capraro, 2015). Students were expected to choose STEM majors if they studied STEM fields in high school. Keeping the continuum of being in a STEM field and then entering a STEM profession was an important factor for increasing the STEM pipeline. This was referred to as "persistence in the STEM pipeline". The persistence of people in the pipeline has been investigated by several researchers (Blickenstaff, 2005; Cannady, Greenwald, & Harris, 2014; Franco, Patel, & Lindsey, 2012; Maltase & Tai, 2010) because a successful pipeline will hopefully bring the expected result: more STEM graduates in the U.S.

The present picture of the pipeline is not as hopeful as educators or industry have expected or wanted. There has been a serious leak in the pipeline (Blickenstaff, 2005; Capraro, 2013; Lee, 2011; Subotnik, Tai, Rickoff, & Almarode, 2009; Xu, 2008). This leakage has been caused by many factors such as high school experiences, classroom experiences, choice of major (Maltase & Tai, 2010), belonging to an underrepresented group, and even gender (Blickenstaff, 2005). The statistics found in the literature were eye-opening with almost 25% of college students majoring in one STEM field and only

50% of these same students graduating with a STEM major (National Center for Education Statistics, 2008). The STEM pipeline metaphor was investigated from another perspective (see Cannady et al., 2014) and it was found that the percentage of students who neither had an interest in STEM fields nor were high achievers of science and mathematics in high school was 72.2%, also 73% of STEM degree holders were successful in mathematics and science or interested in STEM or both. The percentages of college STEM graduates were 94 (both interest and achievement), 76 (interest only), 40 (achievement only), and 21 (neither interest nor achievement), respectively (Cannady et al., 2014). Thus, as seen from the numbers, achievement and interest were very important factors in STEM degree choice.

Picking a STEM major was influenced by different factors, yet it can be combined into two components: achievement and interest. The findings showed that 20% of first year college students' science successes were affected by precollege factors, such as high school calculus, Scholastic Aptitude Test (SAT) scores, advanced placement (AP) science enrollment, science, mathematics, and reading high school grades, education level of parents and ethnicity (Tai, Sadler, & Mintzes, 2006). High school mathematics, SAT mathematics scores, and completion of high school calculus were the most salient factors affecting freshmen science achievement as well as understanding of and time devoted to science in high school (Tai, Sadler, et al., 2006). The intentions of freshmen majoring in STEM and non-STEM fields were investigated and it was found that for STEM inclined freshmen, mathematics abilities, SAT mathematics scores, their willingness to contribute to science were different from their

non-STEM peers (Nicholls, Wolfe, Besterfield-Sacre, Shuman, & Larpkiattaworn, 2007). High school graduation grade point averages, computer skills, and academic abilities were other factors that differentiated STEM and non-STEM major interested students for most ethnic groups from two universities in the northern and southern U.S. (Nicholls et al., 2007). Another study with a group of college participants from Florida revealed that students who took calculus and/or AP calculus courses were more likely to obtain degrees in general (Tyson, Lee, Borman, & Hanson, 2007). The contributions of calculus and/or AP calculus, precalculus, trigonometry and/or analytical geometry and/or probability/statistics to STEM degree attainment were reported as 34.6%, 14.6%, and 10.2%, respectively, whereas general, basic, and consumer mathematics, prealgebra, Algebra 1A or 1B, geometry, Algebra I and II contributed 23.3% to STEM degree attainment (Tyson et al., 2007). Physics I, chemistry II or physics II contributed 18.7% and 39.8%, respectively (Tyson et al., 2007). These results showed the importance of advanced high school mathematics and science course taking on STEM degree attainment and success. Students' interest in STEM is an important factor predicting their future STEM careers. If middle school students have expectations to obtain STEM related careers in the future, specifically defined as physical sciences and engineering, they were 3.4 times more likely to enroll in courses leading to STEM degrees in comparison to others (Tai, Lui, Maltese, & Fan, 2006). In addition, middle school students' mathematics, science and reading abilities were crucial factors that explained the differences in STEM career choice (Nicholls, Wolfe, Besterfield-Sacre, & Shuman, 2010). It was found that 8th grade students who displayed high mathematics achievement

were more likely to earn STEM degrees than others (e.g., Tai, Lui, et al., 2006). For instance, if a student had a mathematics score that was at least one standard deviation higher than the mean, the probability of that students' expectation of obtaining a STEM career was 51%, meanwhile the probability of a student who did not expect to have a STEM career was 19% (Tai, Lui, et al., 2006). These numbers showed the effect of mathematics and science achievement on STEM career choice leading to a STEM field in addition to interest. Therefore, to increase the STEM workforce, all stakeholders need to consider the critical effects of interest, mathematics and science course taking, and math and science achievement on STEM major choice.

Effective activities to improve students' interest in STEM should start as early as possible. To increase students' interest, besides extra-curricular activities, enrolling in a STEM school as a formal learning environment was most important. Focusing on STEM programs in schools was crucial not only for creating STEM literate students but also for having STEM apt students (Kutch, 2011). Supporting youth interest in STEM fields was important in order to meet the needs of humanity (Wyss, Heulskamp, & Siebert, 2012). There have been many studies focusing on the different perspective of high school students' interest in STEM fields (Fang, 2013; Kauffman, Hall, Batts, Bosse, & Moses, 2009; Oh, Ji, Lorentson, & LaBanca, 2013; Robnett & Leaper, 2012; Schneider, Judy, & Mazuca, 2012), however, if an interest in a specific context started early, results would be more positive (Christensen, Knezek, Tyler-Wood, & Gibson, 2014; Heaverlo, 2011; Wyss et al., 2012). It is important to increase student interest in STEM at an early age. In the state of Texas, T-STEM academies have been providing an option for attending

STEM schools at 6th grade, which was the earliest that has been provided so far by T-STEM academies.

Data from the research conducted during this study examined how effective being in a STEM school at an early level was, assuming that exposure to STEM education would make one more college ready especially for STEM majors. Student achievement was measured by the students' scores from the STAAR test. One purpose of this study was to determine the impact of being in a T-STEM academy in the middle grades as opposed to only high school. To determine the impact of being in a T-STEM academy beginning at the 6th grade level, T-STEM academies was divided into two groups. One group was stand-alone T-STEM academies that have only grades 9th-12th. The other group was the stand-alone T-STEM academies that serve as T-STEM academies for grades 6th-12th on the same or different campuses. Therefore, to find reliable and rigorous results, only stand-alone T-STEM academy students were used as participants. The number of stand-alone T-STEM academies was 37 in 2014. Twenty-eight of them served as 6th-12th grade T-STEM academies and nine of them served only high school level students.

Another purpose of this study was to determine the effectiveness of T-STEM academies by the number of years they have been designated as a T-STEM Academy. The number of T-STEM academies has been increasing over the years. In the state of Texas, the very first T-STEM academy was designated during the 2006-07 academic year. After this designation, a T-STEM blueprint with seven benchmarks was inaugurated and must be followed by each T-STEM academy. A *T-STEM Academy*

Design Blueprint Rubric was created to ensure that schools were meeting the required

benchmarks (Avery et al., 2010). In the rubric, seven benchmarks and their

subcomponents were included and it was designed for the first five years of the

academy. The first year was designated as a planning year. Academies were rated based

on four possible criteria. These criteria were: (a) developing, (b) implementing, (c)

mature, and (d) role model. According to the *T-STEM Academy Design Blueprint*

Rubric, an academy was expected to mostly develop and implement some benchmark

subcomponents: year I - mostly implement and develop some benchmark

subcomponents; year II - implement some subcomponents and serve as mature academy;

year III - be a mature academy, implement some subcomponents, and be role model for

implication of subcomponents; and, finally, year IV - be a role model to implement

almost all subcomponents. Thus, one could expect that if a T-STEM academy was

designated for more than 4 years, it would be more experienced than other T-STEM

academies that were in the developing or implementing phase. To analyze this

phenomenon, T-STEM students' standardized test scores were examined by the length

of time of T-STEM academy designation (T-STEM academies serving 4 or more than 4

years and T-STEM academies serving less than 4 years).

CHAPTER II

A LONGITUDINAL EXAMINATION OF T-STEM ACADEMIES' ACADEMIC

PERFORMANCE BY EDUCATION SERVICE CENTERS[*]

Introduction

The Texas Regional Education Service Centers (ESC) System bridges the gap

between the state legislature and needs of the local school districts and public charter

schools. The motto for the system is "World class educational community preparing a

world class workforce" (Texas System of Education Service Centers, 2011, p. 2). The

ESCs assist school districts in improving student performance, enable school districts to

operate more efficiently and economically, and are responsible for implementation of

initiatives assigned by the Texas state legislature or the Commissioner of Education.

There are 20 different ESCs throughout the state of Texas and, they serve more than 4.8

million students, approximately 660,000 administrative and staff members, and over

1,100 school districts (Texas System of Education Service Centers, 2011). They are

financially supported by state and federal grant funds, state appropriated funds, and

revenue generated by the sale of the ESC services (Texas System of Education Service

Centers, 2013).

Each ESC is positioned geographically to address the needs of a diverse state. Texas is composed of a variety of ethnic and economic groups, leading to a diverse population of students, each with different challenges (Texas System of Education Service Centers, 2013). Some ESCs serve primarily urban school districts, whereas others serve rural school districts. The number of school districts per ESC varies from 10 to 100 and the number of students from 40,000 to 1,000,000 (Ausburn, 2010). Each ESC is governed by a board of unpaid directors that is elected by local school members within the region. The ESCs provide support and services that specifically address the local school district and public charter schools' needs (Texas System of Education Service Centers, 2013). The number of services at each ESC varies from 20 to 400 (Texas System of Education Service Centers, 2014). All of the ECSs offer services related to curriculum, leadership, and special programs but vary in what is emphasized. For example, ESCs in urban regions offer services related to Homeless Education along with other topics relevant to a highly populated area, whereas ESCs located in rural areas focus on services that enable teachers and students to access resources that they lack due to small population sizes and remote locations (Ausburn, 2010).

Accountability of Each ESC

ESCs are held accountable by local taxpayers, school districts, the Texas Education Administration, and the Texas Legislature. The accountability of each ESC is measured in different ways such as financial audits, student performance, superintendent and charter school director satisfaction, and an accounting of how much money was saved using the offered resources. Students' performance within each area covered by an

ESC is measured by their results on a series of Texas state standardized tests. These tests measure elementary and secondary level students' knowledge and skills in core subject areas such as mathematics, science, English language arts, and social studies (Texas System of Education Service Centers, 2013).

ESCs and STEM Education

In 1994, the ESC leadership were surveyed to determine what services they felt would be priorities from 2000 to 2019. These leaders believed that topics such as staying on the cutting edge of new trends, innovations, and successful programs in order to better serve school districts were important priorities along with providing professional development related to current trends in order to provide leadership to schools and expertise in mathematics, language arts, science, and social studies. The ultimate goal of the ESCs was to assist the educational community to improve student achievement (Texas System of Education Service Centers, 2011). To achieve that goal, The Texas System of Education Service Centers targeted three objectives. These objectives concerned enlarging the number of districts/campuses/charters to meet the state No Child Left Behind (NCLB) standards, which requires improving students' performance in mathematics and science as well as other subjects (Texas System of Education Service Centers, 2011). However, evaluating "cutting edge" programs and innovations and communicating these findings were lower on the list of priorities (Blackwell, 1995). Furthermore, the integration of technology or engineering into mathematics and science subjects was not amongst the list of priorities and was not mentioned in the strategic plan of Texas System of Education Service Centers for 2010-2015. Only recently have some

ESCs have begun integrating STEM education into their programs. For instance, Region 13 gave information about STEM education and T-STEM academies and Region 5 had a STEM Seminar.

T-STEM Academies

STEM schools in the state of Texas are called T-STEM Academies. T-STEM academies are schools providing science, technology, engineering, and mathematics integrated curriculum to enhance overall success in the STEM area in the state and country. The goals of the T-STEM academies are: (1) to increase students' achievement in STEM subjects (Avery et al., 2010), (2) to develop students' interest in STEM majors and careers as well as promote college readiness (Pantic, 2007; Young et al., 2011), (3) to strengthen teachers through professional development (Educate Texas, 2013a), and (4) to improve students' 21st century skills (Young et al., 2011). T-STEM academies, along with professional development centers and other educator networks, work collaboratively to increase the quality of instruction and students' academic performance in STEM-related subjects at middle and high schools. They are designated by the Texas Education Agency, and as of the 2013-14 educational year, there were a total of 65 T-STEM academies comprised of 59 STEM and 6 STEM/ECHS schools. T-STEM academies are also classified in two categories: T-STEM high schools and T-STEM middle and high schools. Twenty-four of the 59 T-STEM schools served only students in grades 9 through12, and the remainder of the T-STEM academies served students in grades 6 through 12. These academies were well equipped with laboratories that enable

teachers to incorporate innovative instructional methods into their science and mathematics classrooms.

The Influence of Demographics for STEM Students

Students' ethnic backgrounds are an important component of STEM schools. Selective STEM schools are expected to have more high socio-economic status (SES), White, and Asian students than do inclusive STEM schools (Rogers-Chapman, 2013). On the other hand, inclusive STEM academies focus on underrepresented groups. As an example, T-STEM academies have an obligation to serve at least 50% minority groups in each of their schools (Young et al., 2011).

The effect of demographic background on STEM degree attainment has been discussed in research studies. For example, in the state of Florida, even though 21.5% of women obtained baccalaureate degrees, only 9.6% of them were in the STEM related subjects (Tyson et al., 2007). On the other hand, this number was 21.3% for men. The story is different for Asian students; 32.7% out of the 44.5% of Asian students who obtained baccalaureate degrees graduated with a STEM major, whereas the percentages were 12.8% for White, 12.3% for African American, and 14.8% for Hispanic students (Tyson et al., 2007). Tai, Sadler, and Mintzes (2006) also found that, as well as educational background, demographic background, such as ethnicity and parental educational level, was a predictor for college science achievement. In addition, although women took high level mathematics and science courses, they were less likely than men to obtain STEM degrees (Tyson et al., 2007). Therefore, students' demographic backgrounds in T-STEM academies, as well as other STEM schools in the U.S., are very

important predictors of post secondary STEM degree attainment and success.

T-STEM Centers

T-STEM centers assist and support T-STEM academies by creating innovative STEM instructional materials (Bicer et al., 2014; Young et al., 2011) and providing research-based professional development workshops for teachers (Navruz et al., 2014). There are seven T-STEM centers in Texas. These centers offer services that support more than 2,700 teachers and empower their teaching in STEM-related subjects. These centers are located at university campuses and along with the 20 Texas regional educational service centers support T-STEM academies and all other Texas schools located in the region (Educate Texas, 2014). In addition to creating innovative science and mathematics classrooms and delivering professional development workshops to teachers (Bicer et al., 2014; Navruz et al., 2014), these educational centers are also charged with designing innovative STEM curricula and creating partnerships with businesses, universities, and school districts (Educate Texas, 2014). Lately, some ESCs have collaborated with T-STEM centers in the state of Texas to improve the academic achievement of T-STEM academies. However, there were not enough T-STEM academies assigned to each ESC region. Studies related to relationships between regional ESCs and students' academic performances are sparse. Hence, one objective in this study was to examine the effects of services provided by ESCs on outcomes of students in T-STEM academies. This study also provided implications regarding ESCs and T-STEM academies that can inform educational leaders, policymakers, and researchers. The overarching research question was: Do Education Service Centers differ

in how they affect T-STEM Academies' mathematics achievement over several years by gender, ethnicity, and SES? This overarching research question was addressed by answering the following three questions:

1. Do T-STEM Academy students perform differently over time in mathematics?
2. Do T-STEM Academy students' mathematics achievement differ by the Education Service Centers they belong to?
3. Do T-STEM Academy students' mathematics achievement differ by Education Service Centers when gender, ethnicity, and SES are controlled?

Methodology

Participants

The sample consisted of 4,018 high school students attending 26 schools from 11 regions in Texas. The data included three years of TAKS mathematics scale scores. The first measurement for the 9th graders took place in 2009, and the other two measurements occurred in 2010 and 2011. I obtained the same students' scores subsequently for each high school grade (9th, 10th, and 11th) because this is a longitudinal study.

There are 20 regional ESCs in Texas; however, only 11 ECSs contain T-STEM academies. Within these 11 ECSs there are a total of 26 schools represented in this study. The high school students who had at least one TAKS mathematics score among three subsequent years, 2009-2011 were included. Though there are 65 T-STEM

academies, not all of them had students' TAKS mathematics scores available. Moreover, there were some ECSs that did not include at least one measurement for their students.

Among the sample of 4,018 students, 49% were girls. In terms of ethnicity, 63% were Hispanic, 17% were African American, 4% were Asian, and the remaining 16% were White. Also, 61% of the sample was students specified as economically disadvantaged and eligible for free and reduced lunch.

Variables

All independent variables used in the analysis were created using dummy coding.

Level 1. The multivariate format of TAKS mathematics scores for three subsequent years was restructured as the Math variable in a univariate format in order to be analyzed in the HLM version 7 program. In order to indicate which mathematics score was coming from which year, a new variable called Time was created. Time included three levels. Level 0 represented the measurement when students were in 9th grade; level 1 represented the 10th grade measurement, and level 2 represented the 11th grade measurement.

Level 2. Females were coded as 1, and males as 0 in one variable called Female. Because we had four different ethnicities in our sample, we used White as the reference group, and three new dummy coded variables were created. In the variable H, Hispanics were coded as 1, others as 0; in the variable AA, African Americans were coded as 1, others as 0; and similarly AS included 1 for Asian and 0 for others. For the variable DIS, socioeconomically disadvantaged students were coded as 0 and others as 1.

Level 3. ESCs were coded similarly by using region 13 (Austin) as the reference group. Because we have a total of 11 ESCs in our sample, dummy coding created 10 new variables: R1 (Edinburg), R2 (Corpus Christi), R4 (Houston), R5 (Beaumont), R6 (Huntsville), R7 (Kilgore), R10 (Richardson), R11 (Fort Worth), R17 (Lubbock), R19 (El Paso), and R20 (San Antonio).

Data Analysis

HLM version 7 was used to run the longitudinal analysis. Restricted maximum likelihood (REML) was used as an estimation method to generate robust standard error estimates. Three-level hierarchical linear modeling (HLM) was used to analyze the data because the data included three level structures. Three subsequent measurements were nested under the 4,018 high school students, and the students were nested under 26 schools.

The first model was conducted as a three-level unconditional model using only the variables of time and mathematics scores (see Appendix A). The three-level unconditional model was used to determine if students or schools varied in terms of their starting points and slopes. After applying the unconditional model, a new model with level 2 variables, dummy coded ethnicity, gender, and socioeconomically disadvantaged was conducted (see Appendix B). This model provided information on whether or not there are some explained variations coming from level 3 when controlling for the level 2 variables, specifically whether or not there were statistically significant variations between the 26 schools from the 11 ESCs.

The means of three years for the whole sample showed a linear trend. Table 2

displays the descriptive statistics for three subsequent TAKS mathematics scores.

Table 2

Descriptive Statistics for Three Subsequent TAKS Mathematics Scores

	N	Minimum	Maximum	Mean	SD
M9	3744	1063	2955	2105.79	415.99
M10	2403	1288	2786	2204.56	230.07
M11	2050	1316	2839	2285.21	216.29

Estimates for the mean intercept and slope for the students from unconditional

model are shown in Table 3.

Table 3

Final Estimation of Fixed Effects

Fixed Effect	Coefficient	*SE*	*t*-ratio	*d.f.*	*p*-value
Intercept	2195.33	27.14	80.88	25	<0.001
Time (slope)	28.93	11.99	2.41	25	0.024

A statistically significant intercept, 2,195.33, was estimated. This indicated that students' average math score when they were in the 9th grade was 2,195.33. The statistically significant slope, 28.93, indicated that there was a linear growth between measurements.

Table 4

Final Estimation of Level-1 and Level-2 Variance Components

Random Effect	SD	Var*	*d.f.*	χ^2	*p*-value
INTRCPT1, r_0	366.25	134136.36	2477	15885.50	<0.001
TIME slope, r_1	137.64	18944.49	2477	5864.72	<0.001
level-1, e	129.93	16882.30			

*Var: Variance Component

Table 4 demonstrates that there was a statistically significant variation between students' math scores when they are in the 9th grade, and this variance was estimated as 134,136.36. Also, there was a statistically significant variation between students' slopes (18944.49). These statically significant variances' estimates indicated that students did not have same starting points and slopes.

Table 5

Final Estimation of Level-3 Variance Components

Random Effect	SD	Var*	*d.f.*	χ^2	*p*-value
INTRCPT1/INTRCPT2, u_{00}	124.70	15549.78	23	647.45	<0.001
TIME/INTRCPT2, u_{10}	51.01	2601.60	23	388.73	<0.001

*Var: Variance Component

Similarly, Table 5 depicts the variance components in level 3. Based on the results, there was statistically significant variation between schools' starting points and their growths. However, these results came from an unconditional model, so results should be examined when level 2 variables were controlled. Model 2 estimates for the level 2 variables are shown in Table 6.

Table 6

Final Estimation of Fixed Effects

Fixed Effect	Coefficient	*SE*	*t*-ratio	*d.f.*	*p*-value
Intercept	2163.24	14.00	154.59	25	<0.001
Hispanic	-5.92	33.33	-0.18	25	0.860
African American	-163.96	41.22	-3.98	25	<0.001
Asian	-15.48	30.08	-0.52	25	0.611
ED*	37.88	52.73	0.72	25	0.479
Gender	12.11	14.87	0.81	25	0.423
Time	55.67	7.07	7.87	25	<0.001
Time × Hispanic	-6.09	13.78	-0.44	25	0.662
Time ×African American	-0.40	26.74	-0.02	25	0.988
Time× Asian	33.07	11.22	2.95	25	0.007
Time × ED	-13.28	23.18	-0.57	25	0.572
Time ×gender	-15.22	6.91	-2.20	25	0.037

*ED: Economically Disadvantaged

In terms of ethnicities, there were no statistically significant differences between White and Hispanic and White and Asian students when they were in grade 9. However,

African American students' mathematics scores were 163.96 ($p < .001$) points lower than White students' scores on average when they were in 9th grade. There was also no statistically significant difference between male and female students ($p = .423$) when they were in grade 9. In terms of socioeconomic status, there was also no statistically significant difference between socioeconomically disadvantaged and advantaged students in the 9th grade ($p = 0.479$).

In terms of slopes, there were no statistically significant differences between White and Hispanic and also White and African American students. However, Asian students' growth rate was statistically significantly higher than White students' (33.07; $p = 0.007$). There was no statistically significant difference between socioeconomically disadvantaged and advantaged students in terms of their linear growth rates ($p = 0.572$). Male students growth rate was statistically significantly higher than female students' (15.22; $p = 0.037$).

In order to examine the level three variable, ESC, and whether they were statistically significant from each other or not, variance components in level 3 were examined. Because if there was no statistically significant variation between school means, then there was no reason to run a model which included level 3 variables in addition to level 2 variables. Table 7 shows the variance components of level 3 based on the Model 2 that controls the level 2 variables.

Table 7

Final Estimation Of Level-3 Variance Components

Random Effect	SD	Var*	d.f.	χ^2	p-value
INTRCPT1/INTRCPT2, u_{00}	36.01	1296.90	1	2.55	0.106
TIME/INTRCPT2, u_{10}	1.79	3.19	1	0.10	>.500

*Var: Variance Component

Based on Model 2, when controlling for the level 2 variables, there was no variance among schools in terms of their mean intercepts (1,296.90; $p= 0.106$) and their mean slopes (3.19; p>0.500). Thus, there was no reason to find whether there was a statistically significant difference between ESCs' intercepts and slopes because there was no variation between school starting means and their slopes.

Conclusion

According to HLM results, there was a statistically significant difference between T-STEM Academies in different ESCs if the demographic variables were not taken into account. In addition, the demographics of schools are important independent variables and could have affected the dependent variable; therefore, the effect of demographic variables were analyzed. When the demographic variables' effects were analyzed, the results showed that there was not a statistically significant difference between T-STEM Academies in different ESCs. It could be interpreted as the students' academic performance in T-STEM Academies in different ESCs was affected by

demographic variables, and demographic variables were the effective component to create differences between T-STEM Academies in ESCs. Therefore, it was unable to determine if the ESCs differ in their effect on students' mathematical achievement. However, each ESC offers different types of support depending on the needs of their local students, teachers, administration, and other stakeholders. There were no significant differences in the students' mathematical achievement based on the ESC serving them when ethnicity and SES were taken into account. Therefore, this lack of significant differences could indicate that the specialized services offered by the different ESCs are meeting the needs of the diverse student population across the state of Texas.

To further explore the impact of ESCs on their unique student populations' mathematical achievement, future studies must be performed. Besides the TAKS scores, indicators of student achievement, such as college readiness and the results of various new Texas standardized tests, State of Texas Assessments of Academic Readiness, could be analyzed. Also, the serving year of ESCs could be another formative variable, and one could analyze whether there is a statistically significant difference between T-STEM Academies' students' academic achievement in ESCs for serving in different year levels. Because the services provided by the ESCs could impact student achievement at the T-STEM academies, studies explicitly exploring the relationships between ESCs differing services and student achievement should occur.

CHAPTER III

THE INVESTIGATION OF T-STEM ACADEMY STUDENTS' SCORES: A

LONGITUDINAL COMPARISON WITH TRADITIONAL HIGH SCHOOLS

Introduction

People employed in science, engineering, technology, and mathematics (STEM) jobs are expected to shape countries' futures. Beginning in the 21st century, jobs requiring STEM knowledge and skills increased (NRC, 2011a). The prosperity of a country relies on its STEM workforce. Therefore, the U.S. has set a priority of increasing the number of STEM workers (Chen, 2013). The employment in STEM fields is growing. Research findings (U.S. Department of Commerce Economics and Statistics Administration, 2011) demonstrated the value of pursuing a job in the STEM workforce and the need for more STEM workers in the U.S.

To have more individuals in the STEM workforce, students remaining in STEM fields in college need to be ensured. To have sufficient amount of students in post-secondary STEM track, students should be proficient in STEM disciplines at the elementary and secondary levels. However, findings have shown that students' STEM proficiency is unsatisfactory (American College Testing, 2010, 2011, 2013, 2014a, 2014b; Chen, 2013; NRC, 2011a; National Science Board [NSB], 2014). Therefore, stakeholders have recommended corrective actions to improve student achievement in STEM disciplines. Creation of STEM-focused high schools (PCAST, 2010) was one of the critical items out of many recommendations which also included other action items such as improving mathematics and science standards, recruiting, training, and

rewarding teachers (Committee on Science, Engineering, and Public Policy, 2005; PCAST, 2010), and increasing the number of individuals who pursue STEM career (Committee on Science, Engineering, and Public Policy, 2005; NRC, 2011a). Therefore, to increase the number of STEM college graduates, STEM schools were created.

Creation of STEM schools in the U.S. called for the public's attention and large amount investments have given to these schools. That came with the necessity of examination of the effectiveness of these schools. Researchers focused on the success of STEM schools from different perspectives such as academic achievement, interest in STEM, or career choice of students (Almarode et al., 2014; Judson, 2013; Lynch, Behrend, Burton, & Means, 2013; Means, House, Young, Wang, & Lynch, 2013; Means, Wang, Young, House, & Lynch, 2014; Parker, 2010; Oh, Jia, Lorentson, & LaBanca, 2013; Olivarez, 2013; Oner et al., 2013; Oner et al., 2014; Philips, 2013; Thomas, 2000; Tofel-Grehl, 2013; Sahin, Oner, Capraro, 2012, 2013; Wiswall, Stiefel, Schwartz, & Boccardo, 2014). In this study, the effectiveness of these schools was defined as students' academic achievement in mathematics, science, and reading. This study's purpose was to examine the effectiveness of STEM schools by comparing them to demographically similar matched non-STEM schools. One type of STEM schools (i.e., inclusive) was the most common STEM school in the U.S. and Texas had the largest number of these schools. Therefore, in this study, STEM schools in Texas were used to understand the effectiveness of these schools over three years to investigate longitudinal rate patterns.

Types of STEM Schools

STEM schools were born out of specialized mathematics and science schools have been in existence for many years. At the beginning of the 21st century, researchers conducted studies about topics related to STEM schools (e.g., selection procedures [Feldhusen & Jarwan, 1995; Jones, 2010], advantages and disadvantages of STEM schools [Olszewski-Kubilius, 2010], the current model of STEM schools [Means et al., 2008; Pfeiffer, Overstreet, & Park, 2010; Stone III, 2011; Rogers-Chapman, 2013; Thomas & Williams, 2009], and the effectiveness of STEM schools on students' achievement [Erdogan, 2014; Olivarez, 2013; Oner et al., 2013; Oner et al., 2014; Subotnik, Tai, & Almarode, 2011; Wiswall et al., 2014]). In some of these studies, more than one type of STEM schools was investigated (Olszewski-Kubilius, 2010; Rogers-Chapman, 2013; Thomas & Williams, 2009; Tofel-Grehl, 2013) whereas in some, one type of STEM school was examined (Jones, 2010, 2011; Means et al., 2008; Stone III, 2011; Subotnik, Tai, & Almarode, 2011). The report presented by the National Research Council (2011a) identified four types of STEM schools.

The four types of STEM schools are (a) selective STEM schools, (b) STEM-focused career and technical (CTE) schools, (c) inclusive STEM schools, and (d) STEM comprehensive schools. Selective STEM schools educate academically motivated and interested students in STEM disciplines in a very comprehensive environment. These schools have selection criteria to accept students and provide high levels of content with expert teachers for talented students (NRC, 2011b; Olszewski-Kubilius, 2010; Subotnik, Tai, & Almarode, 2011). The second type is STEM-focused career and technical

schools. The purpose of these schools is to nurture students who are expected to be in the STEM workforce (Stone III, 2011). The third type is STEM comprehensive schools. These comprehensive public schools not only emphasize STEM disciplines but also other disciplines much more extensively (NRC, 2011a). The last type is inclusive STEM schools that offer their program to a broader population (NRC, 2011b) because they do not have admissions criteria (NRC, 2011a). They usually provide education to underrepresented students (NRC, 2011a) who are interested in, but not gifted or talented in, STEM (Means et al., 2008).

An inclusive STEM schools: T-STEM academies. The necessity for the creation of STEM schools in Texas has been proven by statistics. The numbers demonstrate the need for STEM workers and suggest how well the state of Texas has done its job. The numbers (NSB, 2014) presented a complex case for elementary and secondary education, however, in terms of post-secondary education, the place in the ranking of Texas became worse than the pre-college case. Table 8 presents detailed information about how well students in Texas performed in terms of science and mathematics achievement in 2011 and Table 9 shows STEM attainment in the post-secondary track during the same year. All of these numbers proved that Texas' contribution to the STEM workforce needed to be improved. Thus, to increase students' achievement level in mathematics and science, and enlarge the number of students who would like to choose a STEM major and pursue STEM career, STEM schools started to open in Texas.

Table 8

4th and 8th Grade Students' Math and Science Performance in Terms of Ranking and Quartile

Math and science achievement	Quartile	Ranking
4th grade math performance	2nd	19
4th grade math proficiency	3rd	26
4th grade science performance	3rd	29
4th grade science proficiency	3rd	34
8th grade math performance	1st	2
8th grade math proficiency	1st	8
8th grade science performance	2nd	25
8th grade science proficiency	3rd	19

Table 9

STEM Attainment of Texas in Post-Secondary Track in Terms of Ranking and Quartile

STEM attainment of Texas in post-secondary track	Quartile	Ranking
Individuals who earned associate's degrees in S, E, & T	3rd	29
18-24 years old people earning bachelor's degree in S&E	4th	49
18-24 years old people earning bachelor's degree in natural S&E	4th	40
25-44 years old people holding post-secondary degree	4th	36
Higher education programs focused on S&E	3rd	24

Note. S&E represents Science and Engineering. S, E, & T represents Science, Engineering, and Technology.

STEM schools in Texas are called Texas STEM (T-STEM) academies. These academies started educating students in 2006. The eligibility of a grant program for creating STEM academy schools (Gonzales, 2010) has led to the establishment of T-STEM academies. In Texas as a whole $54.4 million was dedicated to T-STEM academies in 2006 for the education of high-need, at-risk, economically disadvantaged, English learners, or first-generation college-going students in urban, rural, and border areas (SRI International, 2011). Therefore, the type of T-STEM academies was inclusive (NRC, 2011a) because they were expected to have economically disadvantaged or

minority groups (i.e., at least 50% of the schools population) (Young et al., 2011). Thus, the goal of T-STEM academies should be developing STEM talent (Means et al., 2008) besides their stated goals.

The aim of the T-STEM academies was similar to the other STEM schools in the US. All STEM schools have a goal targeting the improvement of students' mathematics and science performance and enhancing the number of students who want to study and have careers in STEM fields (NRC, 2011a). In addition to the main purpose of STEM schools, the intention of T-STEM academies was to (a) empower teachers and inspire students through professional development (Educate Texas, 2013; TSTEM Blueprint, 2014), (b) expose students to innovative STEM instruction (Texas High School Project [THSP], 2010; TSTEM Blueprint, 2014), and (c) promote school leadership (Educate Texas, 2013). To achieve these goals, T-STEM academies were consistently funded substantially every year.

The funds provided for T-STEM academies were substantial. The fund given to T-STEM academies was $1,730,000 in 2012-2013 alone (S. Avery, personal communication, January 8, 2014). The investment so far has been large that was $133 million until 2012-2013 (Erdogan, 2014). While policymakers have been providing support to STEM schools in Texas, one should think about whether T-STEM academies have actualized the potential of their promise. It is necessary to understand how successful T-STEM academies have been in preparing students mainly from underrepresented groups for the post-secondary STEM path with the help of these substantial resources.

The large funding resource granted to T-STEM academies was one critical reason for investigating the performance of T-STEM academies. Another important reason for conducting this study was the specific design of T-STEM academies. T-STEM academies have their own school design – T-STEM ABD (Avery et al., 2010). The T-STEM ABD covers all components of a well-structured STEM school culture. Therefore, it is expected that their students will outperform their counterparts because T-STEM academies should provide the best instructional strategies including well-prepared STEM teachers. The third reason is the limited number of studies in the literature to understand the performance of T-STEM academies. In addition, the number of studies examining longitudinal aspect of students' success in STEM schools is sparse.

The purpose of this study was to analyze T-STEM academies' success and growth over time to deeply understand the achievement of students' in T-STEM academies and the effect of these schools types on students' academic success compared to their peers in public schools. In this current study, the academic achievement (i.e., science, mathematics, and reading) of students in T-STEM academies over three years (i.e., 2011-2013) was investigated and compared to the counterparts (i.e., students in traditional high schools) including student level variables.

Comparison Studies: STEM versus Non-STEM Schools

Research findings comparing STEM and non-STEM schools were inconsistent. While some study results showed that there was no difference for student achievement between STEM and non-STEM schools (Bicer et al., 2014, 2015; Erdogan, 2014; Philips, 2013; Wiswall et al., 2014); others showed differences (Means et al., 2014;

Philips, 2013; Scott, 2012; Young et al., 2011). Students in STEM schools outperformed in ACT composite and ACT science scores (Means et al., 2014); 9th grade mathematics; 10th grade mathematics and science (Young et al., 2011); exit level reading and mathematics (Scott, 2012). STEM schools also had higher completion rates for advanced course/dual enrollment and higher-education readiness components (Philips, 2013). Female students in STEM schools performed better than their counterparts in non-STEM schools in reading, mathematics (Bicer et al., 2015; Erdogan, 2014), and biology (Wiswall et al., 2014). STEM schools outperformed non-STEM schools with regard to male student performance in science (Erdogan, 2014; Wiswall et al., 2014), mathematics, and reading (Erdogan, 2014).

One goal of STEM schools was to improve minority students' success in STEM disciplines. Results demonstrated that students in STEM schools achieved this goal and Hispanic students had higher scores than Hispanic students in non-STEM schools in mathematics, science (Erdogan, 2014; Wiswall et al., 2014), and reading (Erdogan, 2014). The case was similar for African American students for mathematics and science subjects (Wiswall et al., 2014). White students in STEM schools outperformed White students in non-STEM schools for science (Erdogan, 2014; Wiswall et al., 2014), mathematics, and reading (Erdogan, 2014). Furthermore, White students outperformed African American and Hispanic students in STEM schools in the area of science. However, White students outperformed all others in all subject areas in non-STEM schools (Wiswall et al., 2014). Students, who were economically disadvantaged, performed better than counterparts in non-STEM schools (Erdogan, 2014). They also

outperformed non-economically disadvantaged students in non-STEM schools (Bicer et al., 2015). These studies showed various findings, and the lack of longitudinal studies requires more in depth examination of this phenomena. A longitudinal design was used to explicate the effectiveness of STEM –specifically T-STEM – and non-STEM schools.

Methodology

Students' achievement in mathematics, reading, and science over three years in T-STEM academies and traditional high schools (THS) was examined by using quasi-experimental design. When group assignment is not randomized, the experiments are quasi-experiments (Shadish, Cook, & Campbell, 2002) that test the effect of treatment with presence of control groups and/or pretest measures. In this study, two types of datasets were used: (1) student that included student level variables and (2) school included school level variables. All indicators in both datasets were gathered through TEA's Academic Excellence Indicator System and Public Information Request systems. The data were purchased from TEA and were longitudinal so it was possible to track students over time. Propensity score matching was used to determine participants from THS. To analyze students' achievement in three subjects over time hierarchical linear modeling was used for the analysis of data (e.g., Oner, 2015, Chapter 4).

Participants

For this study, there were 4341 students enrolled in T-STEM academies and THS for the academic years 2010-11, 2011-12, and 2012-13. In total, 50.9% of the participants were female (N_{female}= 2211). The sample demographics consisted of a majority of students being Hispanic (N= 3200, 73.7%), 113 Asian (2.6%), 474 White

(10.9%), and 554 African American (12.8%). There were 2373 students (54.6%) identified as economically disadvantaged by TEA's definition. According to TEA, if a student was eligible for free or a reduced-price meal under the National School Lunch and Child Nutrition Program (TEA, 2009) this student was economically disadvantaged. Other types of economically disadvantaged students included but were not limited to temporary assistance for needy families and students, supplemental nutrition assistance program students, and homeless students. In addition, 43.6% were categorized as "at-risk", who did not perform satisfactorily under defined criteria by TEA (2009).

There were two types of T-STEM academies in the state. One type was the stand-alone T-STEM academy that included all students in the campus. The other type of T-STEM academy was a school-within-a school model where a group of students engaged in a STEM curriculum and the other group engaged in a traditional school program. Because in the data it was not possible to distinguish which students participated in the STEM program in school-within-a school T-STEM academy, only stand-alone T-STEM academies were included in this study. There were 50 T-STEM academies that opened in or before 2011 and were in operation from 2011 to 2013. This is important because a number of schools either had their T-STEM designation revoked or willingly gave it up. However, only 26 of 50 were stand-alone T-STEM academies.

Propensity score matching was used to select comparable non-T-STEM schools (i.e., THS). For propensity score matching, the school dataset was used obtained from TEA. The number of traditional high schools was 1284 in 2011. Out of 8529 schools in Texas, only traditional high schools were selected by eliminating K-8th grades and other

types of schools such as charter, T-STEM, private, and Early College High schools. T-STEM academies were matched based on school characteristics that did not include actual student achievement scores. 26 T-STEM academies were matched to 26 THS. It was possible to lose campuses after matching because student data may not be available in the dataset obtained from TEA for every school. After matching, there were 20 T-STEM academies and 21 THS were available in the dataset.

Some students did not have all scores from each academic subject; therefore, the number of participants in the three academic subjects differed. In addition, to analyze the longitudinal dataset, at least two time-points were required. Thus, students who did not have scores for at least two years were excluded from the analysis. The number of students in mathematics was 4248, in reading 4140, and in science 3306. Science was problematic because it was only tested in grades 10 and 11 so students who missed one assessment were lost to the study.

Independent variables used for student level analyses were: gender, SES (i.e., whether classified as economically disadvantaged), at-risk status, and ethnicity. For school level, a dichotomous variable (i.e., 1 indicated T-STEM and 0 indicated THS) was used to identify whether a school was either a T-STEM academy or THS. To analyze students' growth over time, two variables were developed: time and time-square. For the variable time, 0 indicated intercept (i.e., 2011), 1 indicated year 2 (i.e., 2012), and 2 indicated year 3 (i.e., 2013). The variable time-square was computed by squaring the time variable. The outcome was students' reading, mathematics, and science TAKS scale scores, which was a continuous variable.

Estimation of Student Learning

Students' mathematics, reading, and science achievement was determined by using their high-stake test scores. In the state of Texas, the high-stakes test was TAKS until 2012 (TEA & Pearson, 2013). In 2012, a new test, STARR, was introduced and administered to 9th graders at first. After that, each year the subsequent grade level was added. For instance, in 2012, ninth graders were tested with STAAR, however 10th-11th graders were tested with TAKS. In 2013, STARR was administered for 9th and 10th graders whereas TAKS test for 11th graders. To determine students' change over time, there was a need for a test that was applicable for longitudinal examination. Only, the TAKS test met this condition compared to STARR test, because STARR was an end of course exam. From 2011 to 2013, ninth trough eleventh grade students were the latest group of participants who could provide longitudinal information in Texas for high schools. Therefore, in this study, students' ninth grade TAKS scores in 2010-11, tenth grade TAKS scores in 2011-12, and eleventh grade TAKS scores in 2012-13 were used.

In terms of psychometric characteristics of the test, the reliability estimates were reported. The reliability coefficients for the TAKS test for each academic subject were released each year by TEA. Reliability coefficients for reading and mathematics were: (a) 0.87 and 0.92 in 2011, (b) 0.88 and 0.92 in 2012, and (c) 0.85 and 0.90 in 2013, respectively. For science the reliability coefficient was 0.90 and 0.85 in 2012 and 2013, respectively (TEA & Pearson, 2011, 2013, 2014).

Propensity Score Matching

Propensity score analysis is a useful matching strategy when a researcher does not have randomized experiments and needs a robust design to yield unbiased results. Propensity score matching provides researchers a way to obtain a control group that is similar or close to the treatment group on a pretest basis by taking into account observational covariates. The propensity score is "the conditional probability of being in the treatment condition given set of observational covariates" (Shadish & Steiner, 2010, p. 19), thus its range can be from zero to one. If all relevant covariates are included in the analysis, propensity score analysis could yield unbiased results (Thoemmes & Kim, 2011). However, it is almost impossible to evaluate and include all covariates, but if researchers include as many related-covariates as possible, this can make the strongly ignorable treatment assignment assumption believable (Thoemmes & Kim, 2011), which is needed for removing selection bias in observational studies (Steiner, Cook, Shadish, & Clark, 2010).

In this study, matching two groups (i.e., treatment and control) was conducted by using propensity scores. After the estimation of propensity scores, the matching was conducted. In this study, one-to-one matching was used which is a commonly used matching method (Thoemmes & Kim, 2011). Another reason to use one-to-one matching was the distribution of propensity score. It is important to use one-to-one matching when "closeness of match is critical" (Holmes, 2014, p. 108).

The propensity score matching was conducted using R version 2.14.0. 26 T-STEM academies (i.e., the treatment group) were matched to 26 THS. In the matching,

the percentage of mobility, English proficiency (LEP), SES, at-risk, African American, and Hispanic students were used from the school dataset. The mean percentage of both schools before and after matching was shown in Table 10.

Table 10

Unmatched and Matched Treatment and Control Group Means

	Unmatched		Matched	
Variables	T-STEM Mean	THS Mean	T-STEM Mean	THS Mean
Mobility	14.98	16.76	14.98	15.61
African American	11.77	9.82	11.77	11.43
SES	64.67	51.22	64.67	69.18
Hispanic	62.17	38.36	62.17	59.44
LEP	6.99	4.46	6.99	7.01
At-risk	41.33	43.61	41.33	41.28

The distribution of propensity scores of matched treatment and control units as well as unmatched control units were represented in Figure 1. Unmatched control units were pooled to one side; therefore, it was possible to see using other than one-to-one matching would not give better results.
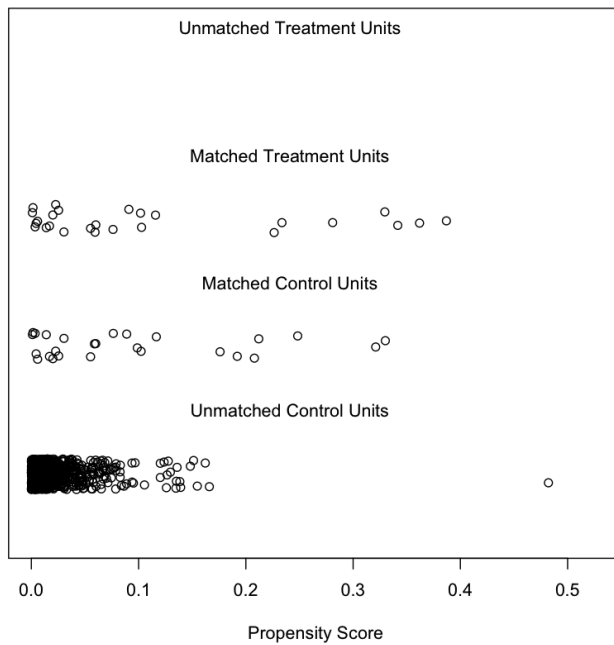
Figure 1. Distribution of propensity scores

Data Analysis

In educational studies, dealing with hierarchical data structures is common because students exist within hierarchical social structures such as classroom, school, or school district (Osborne, 2000). In addition, educational research about students' academic growth is generally nested, that is repeated observations within individuals or student grouped within a hierarchical variable (Raudenbush & Bryk, 2002). These types of nested data structures have some problems. Independence of observations is one assumption that is rarely met in any correlational analysis other than multilevel modeling. Individuals in the nested data, due to its nature, are not fully independent from each other because these individuals tend to show similarities different from people

randomly sampled from the population (Hox, 2002; Osborne, 2000). However, hierarchical linear modeling avoids these problems and is a useful analysis technique for nested data structures (Hox, 2002).

In this study, the data had nested structures: (1) students' scores within students (i.e., time), and (2) students within schools. Therefore, in this study, a three level HLM was used to analyze students' academic achievement over 3 years. Level-1 included students' scores over time. Level 2 included student variables nested within schools. Level 3 included school types (T-STEM or THS).

The fully unconditional model with students' repeated measures, and students nested within schools was the first model analyzed to determine whether the data were appropriate for higher levels (Raudenbush & Bryk, 2002). The reading, mathematics, and science scores were labeled ACHIEVEMENT in every model to keep them generic. The first model equations by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + e_{ijk}$
Level 2 Equation: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
Level 3 Equation: $\beta_{00k} = \gamma_{000} + u_{00k}$

The proportion of variation within and between schools were computed using the formula $\rho = \tau_\beta / \tau_\pi + \tau_\beta$ (Raudenbush & Bryk, 2002). τ_π represented level-2 variance, and τ_β represented level-3 variance.

The second model included a time variable that indicated longitudinal data. The second model by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + e_{ijk}$
Level 2 Equations: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
$\pi_{1jk} = \beta_{10k} + r_{1jk}$
Level 3 Equations: $\beta_{00k} = \gamma_{000} + u_{00k}$

$$\beta_{10k} = \gamma_{100} + u_{10k}$$

There were three time points for mathematics and reading scores of students; therefore, quadratic growth was also taken into consideration. The variable timesq was added to the model. The third model, only for mathematics and reading achievement, by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + \pi_{2jk}*(TIMESQ_{ijk}) + e_{ijk}$

Level-2 Equation: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
$$\pi_{1jk} = \beta_{10k} + r_{1jk}$$
$$\pi_{2jk} = \beta_{20k}$$

Level-3 Equation: $\beta_{00k} = \gamma_{000} + u_{00k}$
$$\beta_{10k} = \gamma_{100} + u_{10k}$$
$$\beta_{20k} = \gamma_{200}$$

In this study, the main focus was to examine the students' scores differences according to two types of schools. Therefore, the school level variable, TSTEM, was one of the important variable that needed to be added to the model. After adding this variable, the model was accepted as base model. The fourth model, base model, by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + \pi_{2jk}*(TIMESQ_{ijk}) + e_{ijk}$

Level-2 Equation: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
$$\pi_{1jk} = \beta_{10k} + r_{1jk}$$
$$\pi_{2jk} = \beta_{20k}$$

Level-3 Equation: $\beta_{00k} = \gamma_{000} + \gamma_{001}(TSTEM_k) + u_{00k}$
$$\beta_{10k} = \gamma_{100} + \gamma_{101}(TSTEM_k) + u_{10k}$$
$$\beta_{20k} = \gamma_{200} + \gamma_{201}(TSTEM_k)$$

For the final model, student level variables were added to the second level of the base model. The student level variables were gender, SES, at-risk status, and ethnicity. The interaction effects of first, second, and third level variables were important to examine the schools' effectiveness in terms of various combination of the variables. In

the final model, after adding student level variables, the third level of the final model had 21 equations for mathematics and reading as well as 14 equations for science. The equations in the second level of the final model were:

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}*(ETH\_A_{jk}) + \beta_{02k}*(ETH\_B_{jk}) + \beta_{03k}*(ETH\_H_{jk}) + \beta_{04k}*(ATRISK_{jk})$$
$$+ \beta_{05k}*(GENDER_{jk}) + \beta_{06k}*(SES_{jk}) + r_{0jk}$$
$$\pi_{1jk} = \beta_{10k} + \beta_{11k}*(ETH\_A_{jk}) + \beta_{12k}*(ETH\_B_{jk}) + \beta_{13k}*(ETH\_H_{jk}) + \beta_{14k}*(ATRISK_{jk})$$
$$+ \beta_{15k}*(GENDER_{jk}) + \beta_{16k}*(SES_{jk}) + r_{1jk}$$
$$\pi_{2jk} = \beta_{20k} + \beta_{21k}*(ETH\_A_{jk}) + \beta_{22k}*(ETH\_B_{jk}) + \beta_{23k}*(ETH\_H_{jk}) + \beta_{24k}*(ATRISK_{jk})$$
$$+ \beta_{25k}*(GENDER_{jk}) + \beta_{26k}*(SES_{jk})$$

Three equations were used for mathematics and reading. Due to lack of timesq variables in science, the last equation was not used for this academic subject.

As an estimation method, full maximum likelihood (FML) was used in the analysis. For three level models in HLM 7 software, the default estimation method is FML. FML is one of the estimation method for three level models (see Raudenbush & Bryk, 2002). The sample size of groups in this study were not equal. For unbalanced data, FML was suggested as an estimated method (Garson, 2013); therefore, FML was used in this study.

Process for accounting for time. For quadratic growth, the growth rate at each year can be computeed by using the derivate of the level 1 equation. For instance, $ACHIVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + \pi_{2jk}*(TIMESQ_{ijk}) + e_{ijk}$, the average growth rate at the end of the second year (i.e., 2012) for mathematics and reading would be $t = \pi_{1jk} + 2*\pi_{2jk}*(2012\text{-}2011)$ (see Raudenbush & Bryk, 2002).

Results

Key Features of the Data

Descriptive statistis were reported to gain insights about the variables included in the models. Means and standard deviations were reported for the baseline year across the following variables: (a) mathematics, (b) reading, (c) science, (d) gender, (e) ethnicity, (f) at-risk status, and (g) SES (i.e., economically disadvantaged status) (see Table 11). Male students' mathematics and science scores were higher than female students whereas female students had higher scores in reading. Not-at-risk students outperformed at-risk students in the three academic subjects. In terms of ethnicity, White students scored higher than other students in mathematics and reading whereas Asian student scores were higher than others in science. Hispanic students' scores were higher than African American and Asian students in mathematics and reading. White students outperformed Hispanic and African American students in science. In mathematics, the score ranking from highest to the lowest in terms of ethnicity was White, Hispanic, Asian, African American; in reading was White, Hispanic, African American, and Asian; and in science was Asian, White, Hispanic, and African American, respectively. Not economically disadvantaged students outperformed economically disadvantaged students in mathematics and science, whereas economically disadvantaged students scored slightly higher than not economically disadvantaged students in reading.

Table 11

Students' Scores in Mathematics, Reading, and Science in the Baseline Year

		Mathematics		Reading		Science	
Variable	Category	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$	*SD*
Gender	Female	2231.41	287.96	2288.80	246.57	2215.55	166.95
	Male	2236.36	311.14	2258.38	247.86	2256.70	179.64
At-risk status	At-risk	2073.66	333.28	2144.62	282.20	2149.02	161.42
	NAT*	2317.02	241.45	2341.48	196.32	2281.96	163.07
Ethnicity	Asian	2177.47	625.91	2134.61	472.57	2354.23	176.92
	AA**	2163.14	223.16	2244.95	176.83	2204.25	162.84
	Hispanic	2234.69	296.08	2272.93	250.98	2227.10	170.04
	White	2319.61	269.92	2283.68	253.73	2306.24	190.12
SES	ED***	2203.01	295.40	2274.78	251.42	2218.01	169.01
	NED****	2280.70	299.48	2272.48	240.21	2274.58	179.94

*NAT: Not at-risk
**AA: African American
***ED: Economically disadvantaged
***NED: Not economically disadvantaged

Students' scores for three years were represented to show their trajectory in three academic subjects (see Table 12). In mathematics, students' scores in 2011 and 2012 did not change, but increased in 2013. In reading, all students' scores showed positive parabolic trend. Students scores in 2012 were lower than socres in 2011 and 2013 in reading. Students' scores for science increased over time.

Table 12

Students' Mean Score and Standard Deviations in Academic Subjects for Three Years

Year	Mathematics		Reading		Science	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
2011	2233.83	299.40	2274.00	247.63		
2012	2233.52	185.37	2264.59	147.27	2235.48	174.40
2013	2282.24	193.72	2287.05	166.44	2280.25	164.17

The 95% CIs for the means of reading, mathematics, and science for T-STEM academies and THS are displayed in Figures 2, 3, and 4. For each academic subject, T-STEM academies' mean scores were higher than their counterparts for every year. For mathematics, the mean score for second year of T-STEM academies was lower than their first and third year scores. However, the growth of the THS's mathematics scores tended to be linear and positive. In addition, T-STEM academies' third year mathematics score was slighly higher than their first year; however, THS's third year score was statistically significantly higher than their first year. This implied that, THS had lower scores than T-STEM academies in mathematics; however, THS's change over time was more positive accompanied by a faster rate of change than their counterparts (see Figure 2).
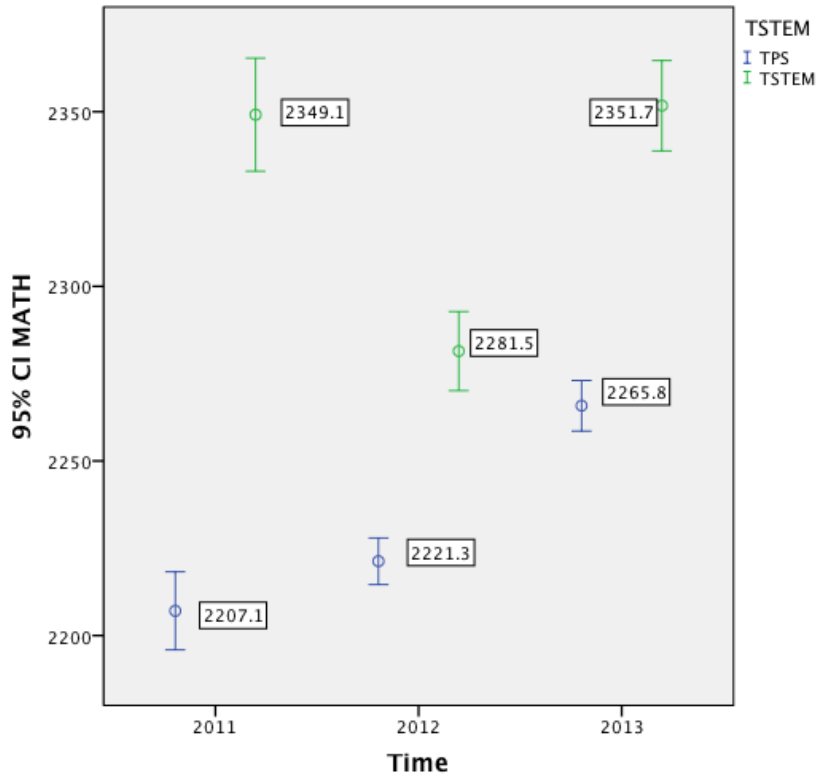
Figure 2. 95% CI for mean of mathematics achievement for T-STEM academy and THS in three years

The trends for T-STEM academy and THS for reading were similar to those for mathematics (see Figure 3). The only difference in reading was that T-STEM academies' third year mean was lower than their first year mean whereas THS's third year mean was higher than their first and second year means.
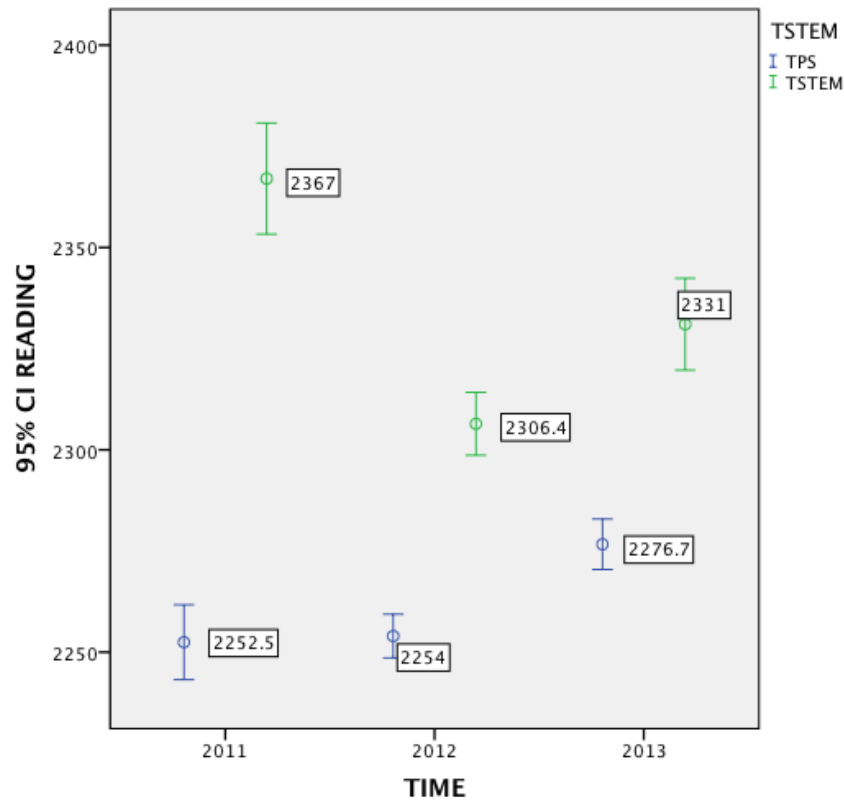
Figure 3. 95% CI for mean of reading achievement for T-STEM academy and THS in three years

The slopes for science achievement for T-STEM academies and THS were nearly parallel. The mean T-STEM academies baseline score was higher than counterparts and their second year score was higher than THS as well. THS science slope was steeper than T-STEM (see Figure 4).
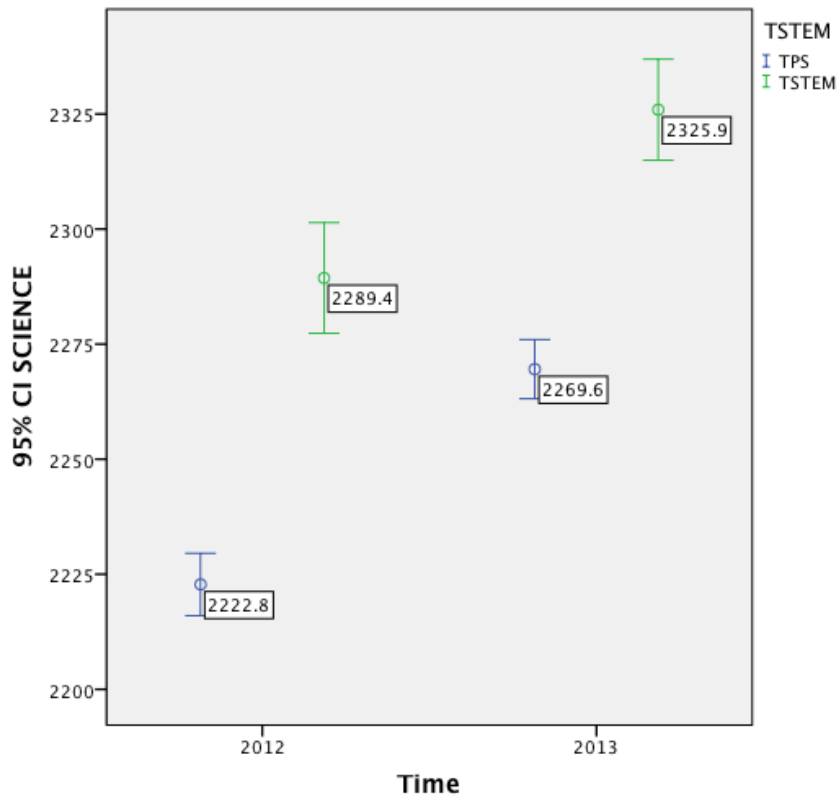
Figure 4. 95% CI for mean of science achievement for T-STEM academy and THS in two years

HLM Analyses

The three level HLM analysis was executed using HLM 7 software to determine students' growth over time for mathematics, reading, and science in T-STEM academies and THS.

Unconditional model. The unconditinal model was used to determine how much of the variation in the outcome variable was within and between schools. The grand mean (γ_{000}), the estimated within-school variance (τ_π), and between-school variance (τ_β)

were shown in Table 13 for each academic subject. According to the unconditional

model, 83% of the variation in mathematics achievement was within schools whereas

16% was between schools. 86% of the variation in reading was within schools and 13%

was between schools. In science, the within school variation was 82% and between

school variation was 18%.

Table 13

Grand Mean, Within and Between School Variance for Mathematics, Reading, and

Science Scores

Subject	Grand mean	Within-school variance (τ_π)	Between-school variance (τ_β)
Mathematics	2268.25	25639.95	5052.52
Reading	2295.25	15390.95	2426.66
Science	2273.53	12553.49	2803.34

The final model. The fourth model included student level and school level

variables. The results of HLM analysis were represented in Table 14 for three academic

subjects. The main effects of time, timesq, at-risk, Asian, African American, SES, were

statistically significant ($p<0.05$) in the initial year for mathematics. Some interaction

effects for mathematics scores of students were statistically significant ($p<0.05$): (1)

TSTEM ×Asian, (2) TSTEM × at-risk, (3) TSTEM × SES, (4) time × Asian, (5) time ×

TSTEM × Asian, (6) time × Hispanic, (7) time × African American, (8) time × at-risk,

(9) time × TSTEM × at-risk, (10) timesq × gender, (11) timesq × Asian, (12) timesq × TSTEM × Asian, (13) timesq × African American, (14) timesq × Hispanic, (15) timesq × at-risk, (16) timesq × TSTEM × at-risk. The main effects of time, timesq, TSTEM, gender, Asian, at-risk, Hispanic were statistically significant ($p<0.05$) in the initial year for reading. Some interaction effects for reading scores of students were statistically significant ($p<0.05$): (1) TSTEM × Asian, (2) TSTEM × at-risk, (3) time × gender, (4) time × Asian, (5) time × Asian × TSTEM, (6) time × at-risk, (7) timesq ×gender, (8) timesq × Asian, (9) timesq × Asian × TSTEM, and (10) timesq × at-risk. The main effects of gender, African American, Hispanic, at-risk were statistically significant ($p<0.05$) in the initial year for science. Statistically significant interaction effets in science were: (1) time × African American × TSTEM, (2) time × Hispanic, and (3) time × at-risk.

The γ_{000} coefficient represented the predicted initial year of White, not-atrisk female not economically disadvantaged (NED) student in a THS (i.e., reference student). For such as student in the predicted mathematics (reading, and science) achievement was 2334.30 (2386.20 and 2291.29). On average, such students in T-STEM academies scored 26.46, 29.55, and 37.26 points higher than students in THS in mathematics (M), reading (R), and science (S), respectively. If student was an Asian not-atrisk female NED, the average score decreased 422.48 (M) and 422.61 (R) whereas increased 20.13 (S) points; if the student was an African American not-atrisk female NED, the average score decreased 67.67 (M), 25.48 (R), and 42.02 (S); and if the student was Hispanic not-atrisk female NED, the average score decreased 14.90 (M), 30.62 (R), and 42.60 (S)

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points. However, for an Asian not-atrisk female NED student in a T-STEM academy, the average score increased 129.22 (M) and 46.56 (S) but decreased 12.25 (R) points; if the student was an African American not-atrisk female NED in a T-STEM academy, average mathematics and reading achivement increased 492.03 and 447.56, points whereas decreased 74.66 points for science; and if the student was Hispanic not-atrisk female NED in a T-STEM academy, average mathematics, and reading achivement increased 19.26 and 41.20 points but science achievement decreased 88.72 points. For a White not at-risk male NED student in a THS, the initial average mathematics, reading, and science scores were 2347.58, 2345.30, and 2328.13. However, for White not at-risk male NED students in a T-STEM academy, the average mathematics, reading, and science scores increased 30.61, 4.62, and 87.75 points. A typical White at-risk female NED student in a THS scored 2095.12 (M), 2175.26 (R), and 2164.69 (S) on average; however such students scored 83.09 (M), 87.36 (R), and 100.04 (S) points lower in a T-STEM academy in mathematics, reading, and science, respectively. On average, White not at-risk female economically disadvantaged (ED) students in a THS scored 46.53 (M), 4.77 (R), and 20.75 (S) points lower than grand mean; however such student's score in a T-STEM academy increased 95.90 (M) and 104.45 (R) whereas decreased 2.26 (S) points.

The predicted learning rate for the reference student group was -126.99, -75.64 and 17.89 for mathematics, reading, and science, respectively. On average, a reference group student's mathematics and reading scores decreased 126.99 and 75.64 points but their scicence score increased 17.89 points per year. However, on average, a T-STEM

academy student's learning rate decreased 119.83 (M) and 94.78 (R) points, whereas the science learning rate increased 13.46 points per year. On average, Asian not-atrisk female NED students' mathematics, reading, and science learning gain was 557.23, 415.78, and 49.12 points; African American not-atrisk female NED students' their learning rate decreased 0.29 (M), 79.78 (R), and 9.31 (S) points; Hispanic not-atrisk female NED students' their learning rate decreased 72.26 (M), 42.03 (R), and increased 46.57 (S) points. On average, the learning rate decreased 218.71 (M), 54.93 (R), and increased 14.73 (S) points for Asian not-atrisk female NED students in T-STEM academies. On average, the learning rate decreased 132.43 (M), 88.55 (R) and 7.02 (S) points for Hispanic not-atrisk female NED students in T-STEM academies. On average, for an African American not-atrisk female NED student in a T-STEM academy, the learning rate decreased 0.88 (M), 99.44 (R), and 262.02 (S) points. On average, the learning rate for a White at-risk female NED student in a THS increased 2.82 (M), 20.72 (R), and 47.33 (S) points. On average, for a White at-risk female student NED in a T-STEM academy, the mathematics and reading learning rate per academic year decreased 105.90 and 35.29 points whereas increased 31.39 points in science. On average, for a White not at-risk male NED student in a THS, the learning rate per year was -1430.63 (M), -104.77 (R), and 18.79 (S) points. If student was a White not at-risk male NED student in a T-STEM academy, the average learning rate per year decreased 96.16 (M) and 106.26 (R) points but increased 8.88 points in science. On average, for a White not at-risk female ED student in a THS, the learning rate decreased 118.67 (M) and 72.98 (R) whereas increased 16.13 (S) points. If student was a White not at-risk female ED

student in a T-STEM academy, the average learning rate per year decreased 129.98 (M) and 110.45 (R) points but increased 69.25 points in science.

The mean accelaration was statistically significant ($p<0.001$) and positive (γ_{200}=55.89 and γ_{200}=22.84) in mathematics and reading. From the descriptive analysis, it was seen that schools growth was not linear for mathematics and reading performance. Therefore, there was a need for a variable (i.e., timesq) to estimate the accelaration rate of schools to examine their growth rate over time. At the end of the second year, the average growth rate for White not-atrisk female NED student in a THS was -15.21 (M) and -29.94 (R) points per year. For such students, by the end of the third year, the average growth rate had grown to 96.56 (M) and 15.75 (R) points per year. For a White not-atrisk female NED student in a T-STEM academy, the average growth rate was -8.09 (M) and -13.77 (R) at the end of the second year. By the end of the third year, the average growth rate had grown to 103.70 (M) and 67.22 (R) points per year for a White not-atrisk female NED student in a T-STEM academy. The average growth rate for an Asian not-atrisk female NED student in a THS was 103.67 (M) and 117.39 (R) points per year by the end of the second year, whereas -222.85 (M) and -105.35 (R) points per year by the end of third year. The average growth rate for an Asian not-atrisk female NED student in T-STEM academy was -144.81 (M) and -85.20 (R) points per year by the end of the second year, whereas -70.92 (M) and -115.47 (R) points per year by the end of third year. The average growth rate for an African American not-atrisk female NED student in a THS was -137.40 (M) and -76.68 (R) points per year by the end of second year, whereas -147.51 (M) and 2.05 (R) points per year by the end of third year.

However, for an African American not-atrisk female NED student in a T-STEM academy, the average growth rate was -210.16 (M) and -220.81 (R) points per year by the end of second year, whereas -419.43 (M) and -342.19 (R) points per year by the end of third year. The average growth rate for a Hispanic not-atrisk female NED student in a THS was -111.49 (M) and -54.52 (R) points per year by the end of second year, whereas -23.72 (M) and 8.63 (R) points per year by the end of third year. However, for a Hispanic not-atrisk female NED student in a T-STEM academy, the average growth rate was -131.03 (M) and -92.30 (R) points per year by the end of second year, whereas -129.63 (M) and -96.06 (R) points per year by the end of third year. The average growth rate for a White atrisk female NED student in a THS was -62.88 (M) and -37.03 (R) points per year by the end of second year, whereas -1.59 (M) and -19.15 (R) points per year by the end of third year. The average growth rate for a White atrisk female NED student in a T-STEM academy was -79.61 (M) and -76.78 (R) points per year by the end of second year, whereas -53.31 (M) and -118.26 (R) points per year by the end of third year. The average growth rate for a White not-atrisk male NED student in a THS was -120.02 (M) and -72.64 (R) points per year by the end of second year, whereas 30.59 (M) and 35.13 (R) points per year by the end of third year in mathematics and reading. However, for a White not-atrisk male NED student in a T-STEM academy, the average growth rate was -99.85 (M) and -101.96 (R) points per year by the end of second year, whereas -103.54 (M) and -97.66 (R) points per year by the end of third year. The average growth rate for a White not-atrisk female ED student in a THS was -124.13 (M) and -67.26 (R) points per year by the end of second year, whereas -2.59 (M) and 14.10

(R) points per year by the end of third year in mathematics and reading. However, for a White not-atrisk female ED student in a T-STEM academy, the average growth rate was -118.30 (M) and -99.57 (R) points per year by the end of second year, whereas -106.63 (M) and -88.68 (R) points per year by the end of third year.

Discerning practical importance. The χ^2 statistics accompanying the variance components showed statistically significant variation among students within schools for the initial year in mathematics, reading, and science. In addition, the variations in the learning rates were statistically significant within schools in mathematics and reading. Between schools, there was statistically significant variation for the mean scores for the initial year for all three academic subjects as wells as for the learning rate for mathematics. The variable TSTEM accounted for 58%, 63% and 43% of the variation in the initial year in mathematics, reading, and science, respectively. TSTEM also explained 30% and 63% of the variation of the learning rate between schools in mathematics and reading, respectively. All student level variables (i.e., SES, gender, at-risk, ethnicity) added to the model accounting for 20%, 22%, and 24% of the variation in the initial year for all three subjects. Student level variables accounted for 10% and 8% of the variation in growth rate for mathematics and reading.

Table 14

Effects of Student and School Level Variables on Students' Mathematics, Reading, and Science Achievement

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Intercept	2334.31*	18.69	124.89	2368.21*	15.06	157.28	2291.30*	10.71	214.03
TSTEM	26.46	34.60	0.77	29.55	29.75	0.99	37.27	20.57	1.81
Asian	-422.48*	44.39	-9.52	-422.67*	35.96	-11.75	20.13	42.08	0.48
TSTEM × Asian	560.84*	63.24	8.87	412.44*	50.91	8.10	12.79	52.59	0.24
AA**	-67.67*	22.36	-3.03	-25.48	16.77	-1.52	-42.02*	15.50	-2.71
TSTEM × AA**	-1.13	62.74	-0.02	60.60	48.85	1.24	-45.43	29.20	-1.56
Hispanic	-14.91	18.31	-0.81	-30.62*	13.68	-2.24	-42.60*	13.51	-3.15
TSTEM × Hispanic	35.31	42.15	0.84	11.12	27.44	0.41	-0.69	31.94	-0.02

Table 14 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
At-risk	-239.18*	9.68	-24.71	-192.94*	7.90	-24.44	-126.61*	11.30	-11.20
TSTEM × at-risk	120.78*	29.09	4.15	94.46*	22.79	4.14	27.25	18.75	1.45
Gender	13.28	9.04	1.47	-22.90*	7.51	-3.05	36.84*	5.91	6.24
TSTEM × gender	-9.13	21.05	-0.43	-2.02	17.47	-0.12	13.64	11.95	1.14
SES	-46.54*	11.27	-4.13	-4.77	7.89	-0.61	-20.75	13.75	-1.51
TSTEM × SES	21.66	32.46	0.67	14.77	18.33	0.81	-8.77	26.06	-0.34
Time	-127.00*	20.70	-6.14	-75.64*	19.94	-3.79	17.90	12.09	1.48
Time × TSTEM	7.10	41.53	0.17	-19.14	41.52	-0.46	-4.43	22.30	-0.20

Table 14 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Time × Asian	684.23*	67.38	10.15	491.43*	60.28	8.15	31.23	30.86	1.01
Time × TSTEM × Asian	-783.04*	89.38	-8.76	-451.58*	79.98	-5.65	-29.96	36.47	-0.82
Time × AA**	126.70*	26.47	4.79	-4.14	22.87	-0.18	-27.21	22.67	-1.20
Time × TSTEM × AA**	-7.69	85.31	-0.09	-0.52	74.32	-0.01	-248.28*	39.85	-6.23
Time × Hispanic	54.73*	21.61	2.53	33.61	18.85	1.78	28.68*	11.84	2.42
Time × TSTEM × Hispanic	-67.27	54.04	-1.25	-27.38	37.99	-0.72	-49.17	38.75	-1.27

Table 14 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Time × at-risk	129.82*	12.98	10.00	96.37*	11.83	8.14	29.44*	6.57	4.48
Time × TSTEM × at-risk	-115.83*	36.76	-3.15	-36.89	32.63	-1.13	-11.51	19.90	-0.58
Time × gender	-16.64	12.29	-1.35	-29.14*	11.26	-2.59	0.90	5.26	0.17
Time × TSTEM × gender	40.37	28.57	1.41	17.65	26.10	0.68	-5.48	11.00	-0.50
Time × SES	8.32	13.38	0.62	2.66	11.84	0.23	-1.76	9.15	-0.19
Time × TSTEM × SES	-18.41	43.50	-0.42	-18.33	27.54	-0.67	57.55	33.99	1.69

Table 14 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Timesq	55.89*	9.39	5.95	22.85*	9.31	2.45			
Timesq × TSTEM	0.01	19.11	0.00	17.65	19.37	0.91			
Timesq × Asian	-226.78*	31.66	-7.16	-149.20*	28.56	-5.23			
Timesq × TSTEM × Asian	263.73*	41.42	6.37	134.06*	37.42	3.58			
Timesq × AA**	-68.55*	12.04	-5.70	1.55	10.69	0.15			
Timesq × TSTEM × AA**	-36.08	47.82	-0.76	-62.24	41.44	-1.50			
Timesq × Hispanic	-19.61*	9.85	-1.99	-6.25	8.80	-0.71			

Table 14 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Timesq × TSTEM × Hispanic	20.31	25.06	0.81	4.37	17.73	0.25			
Timesq × at-risk	-32.85*	5.96	-5.51	-28.88*	5.49	-5.27			
Timesq × TSTEM × at-risk	46.00*	16.70	2.76	8.14	15.13	0.54			
Timesq × gender	11.81*	5.65	2.09	16.07*	5.21	3.08			
Timesq × TSTEM × gender	-13.65	13.00	-1.05	-13.92	11.97	-1.16			

Table 14 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Timesq × SES	-2.73	5.99	-0.46	2.86	5.48	0.52			
Timesq × TSTEM × SES	8.57	20.00	0.43	2.58	12.67	0.20			

*p<0.05
**AA: African American

Conclusion

This study contributes to the literature by determining the effectiveness of T-STEM academies on students' academic achievement compared to traditional high schools. The results show that there was no statistically significant difference between T-STEM academies and TPS longitudinally for mathematics, reading, and science. Similar results have been found by others (e.g., Bicer et al., 2014, 2015; Erdogan, 2014; Philips, 2013; Wiswall, 2014). However, there were some differences in terms of student level variables. There were statistically significant interaction effects between growth and some student variables in T-STEM academies and traditional public schools in this study.

The results for mathematics mostly were in T-STEM academies favor compared to TPS. Students in T-STEM academies started with higher mathematics mean scores; however, there was no statistically significant difference by T-STEM academies and TPS (see Figure 1). Asian and at-risk students in T-STEM academies started with higher scores than their counterparts in mathematics and their growth over time increased compared to TPS counterparts. This showed that T-STEM academies performed well for at-risk students in mathematics. This is important because at-risk students are a critical group of students who are underrepresented in STEM majors (Street et al., 2012).

Hispanic students, another underrepresented group showed greater positive mathematics growth over time as compared to their counterparts in TPS. There were parallel findings in the literature showing the effect of TSTEM academies on Hispanic students' mathematics achievement (Bicer et al., 2014, 2015; Erdogan, 2014; Philips,

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2013; Wiswall, 2014). For economically disadvantaged students, the mathematics instruction in T-STEM academies showed increases in their standardized test scores (Bicer et al., 2015; Erdogan, 2014). This result was aligned to the goals for T-STEM academies because they are expected to serve and increase achievement for minority and economically disadvantaged students' (Young et al., 2011).

The results for reading achievement varied for different student profiles. Even though T-STEM academies' mean was higher than their counterparts in the initial year, they had dramatic decrease in their second year (see Figure 2) for reading. There were two promising findings for T-STEM academies that was Hispanic and Asian students' growth over time was positive. A very concerning result was the continual decrease of economically disadvantaged and African American students' means in T-STEM academies. This showed that TPS served better for low SES and one group of minority (i.e., African American) students in reading. In conclusion, the reading instruction in T-STEM academies was not helpful for male, African American, and economically disadvantaged students. However, it is important to take the purpose of T-STEM academies into consideration, which was to improve students' mathematics and science performance (Educate Texas, 2013; NRC, 2011a), while evaluating the findings for reading.

The results for science were mixed. There was one encouraging finding for T-STEM academies and that was economically disadvantaged students showed positive growth overtime. However, African American and Hispanic, two underserved groups in STEM, students were better served in TPS. Perhaps the most troubling is that Hispanic

students in T-STEM schools showed a continual decrease. In addition, the science achievement findings for male students decreased over time and this showed similarities in others' work (e.g., Wiswall et al., 2014).

T-STEM academies are expected to use STEM practices (i.e., project based learning and problem based learning); however, poorly implemented STEM practices might impair learning instead of improving it. Had the implementation been better it is possible that the instructional strategies would have been more effective for science learning. Another potential problem is that the delivery of the content is very important. If there was not sufficient emphasis on building teachers' integrated teaching knowledge it would be hard to successfully implement a STEM curriculum or to fully implement STEM project based learning. Therefore, if teachers in T-STEM academies are not well prepared, and perhaps prepared differently than traditional teachers, with requisite knowledge and skills, it is inevitable to get undesired results in STEM schools.

CHAPTER IV

THE EFFECT OF T-STEM DESIGNATION ON CHARTER SCHOOLS: LONGITUDINAL EXAMINATION

Introduction

In the early 2000s policymakers pointed out the need for establishment of STEM schools in the U.S. (Committee on Science, Engineering, and Public Policy, 2005; PCAST, 2010) The reason of the call for establishing STEM schools was the insufficient number of students pursuing STEM degrees and people in STEM careers. Opening STEM schools was a suggestion in order to increase the number of STEM interested students. After the suggestion proposed by policymakers, the number STEM schools has been increasing in the U. S. with the aim of improving student achievement in STEM disciplines and enhancing the number of students interested in STEM.

The state of Texas showed continuous growth in terms of the number of designation of STEM schools. There were seven STEM schools in 2006-07 and it increased to 65 in 2012-13. Sixty-five schools were designated from different types of schools such as traditional high school or charter schools. The percentage of stand-alone STEM schools in Texas (i.e., T-STEM academies), which were converted from charter schools, was 92. This indicated that while the number of T-STEM academies has been increasing, the number of T-STEM charter schools has been increasing as well.

The percentage of stand-alone T-STEM charter schools was a noteworthy number to investigate the reason behind the transformation of charter schools to T-STEM academies. In this study, students' achievement in T-STEM charter schools and

non-T-STEM charter schools were compared in order to examine the differences between two types schools. It could be expected that the results of the study would lead us to determine why charter schools needed to transform into T-STEM academies.

Charter Schools

Charter schools were brought to the attention of the U.S. as a new promising school type at the beginning of the 1990s. This school type started to be an agenda item for a better education after the release of "A Nation at Risk: The Imperative for Educational Reform" (1983) report (Weil, 2000). The report was a wake up call for stakeholders about the failures of public schools and especially insufficient education of youth in the U.S. (Barr, Sadovnik, & Visconti, 2006; Salinas, 2013).

To have a more successful educational setting, charter schools opened as an alternative to public schools including new and innovative opportunities and emphasizing specifically accountability for students' performance (Salinas, 2013; Weil, 2000). Charter schools were public schools under contract that were disentangled from many regulations, however, accountable for students' performance (Barr et al., 2006; Gooch, 2013; Weil, 2000). The academic accountability was crucial for charter schools. If they are not successful in students' reaching the proficiency level, they are subject to closure. Therefore, improvement of students' performance was the most critical goal for charter schools.

Charter Versus Public Schools

Although charter schools were offered as a choice for parents and communities to increase students' achievement, the success of these schools was inconsistent. The

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What Works Clearinghouse (WWC) committee examined 12 studies related to charter schools. Eight studies out of 12 demonstrated that charter school students outperformed traditional public school students in mathematics (Center for Research on Education Outcomes [CREDO], 2010, 2011, 2012; Tuttle, Gill, Gleason, Knechtel, Nichols-Barrer, & Resch, 2013; Tuttle, Teh, Nichols-Barrer, Gill, & Gleason, 2010; Woodworth, Davis, Guha, Wang, & Lopez-Torkos, 2008), science (Tuttle et al., 2013), reading (CREDO, 2010, 2011, 2012, 2013; Tuttle et al., 2010; Tuttle et al., 2013), English language arts (Angrist, Chodes, Dynarski, Pathak, & Walters, 2014; Woodworth et al., 2008), social studies (Tuttle et al., 2013), Academic Performance Index (Toney & Murdock, 2008), and Scholastic Aptitude Test scores (Angrist et al., 2014) in different grade levels. In addition to WWC reports, the other studies results demonstrated that charter school students had higher reading (Barr et al., 2006; Gutierrez, 2012; Pardo, 2013; Rose 2013) and mathematics scores than their peers (Barr et al., 2006; Choi, 2012; Pardo, 2013; Rose, 2013; Sahin, Willson, & Capraro, 2013). However, WWC reports showed in some studies, charter school students performed the same as their peers in reading (Furgeson et al., 2012; Gleason, Clark, Tuttle, & Dwoyer, 2010), mathematics (CREDO, 2013; Furgeson et al., 2012; Gleason et al., 2010), science, and social studies (Furgeson et al., 2012) as well as AP exam passing rate (Angrist et al., 2014). Moreover, it was shown that traditional public school students outperformed charter school students in reading (CREDO, 2009; Gutierrez, 2012; Sahin et al., 2013; Shrout, 2009), mathematics (CREDO, 2009; Gutierrez, 2012; Hinojosa, 2009; Sahin et al., 2013; Shrout, 2009; Turner, 2013), and science (Hinojosa, 2009; Turner, 2013). Furthermore, the drop out

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rate for traditional public schools was significantly lower than charter schools (Hinojosa, 2009; Rose, 2013). Finally, it would be hard to provide a definite answer to the effectiveness of charter schools.

STEM Schools

Although schools focusing strongly on STEM disciplines, educating gifted and talented students have been around for over one-hundred years, "STEM schools" as they are known today have been in operation since the 1980s (Thomas & Williams, 2009). A general malaise began to creep into the American educational system as the realization that more students needed to be successful and interested in STEM disciplines and careers. It was important to establish U.S. STEM workers in leadership positions so the U.S. could retain prominence in the global marketplace (Atkinson, Hugo, Lundgren, Shapiro, & Thomas, 2007). Publication of "Rising Above the Gathering Storm" report (2005) ushered in the era of intensified interest and attention to STEM education, STEM fields, and preparing the next generation of STEM professionals. In response to the call, the creation of 1000 STEM schools was one of the recommendations to increase the number of STEM graduates and individuals in the STEM workforce (President's Council of Advisors on Science and Technology [PCAST], 2010). The effectiveness of these schools started to be the object of interest as the number of STEM schools began to steadily increase.

STEM Versus Non-STEM Schools

The main purpose of STEM schools was to improve students' achievement in STEM disciplines. To understand the effectiveness of STEM schools on students'

academic achievement, researchers compared students' academic achievement in STEM

schools to non-STEM schools.

The findings from comparison studies varied. For instance, students' in STEM

schools had higher American College Testing composite and science scores than their

counterparts (Means et al., 2014). In addition, students in STEM schools outperformed

non-STEM school students in 9th grade mathematics, 10th grade mathematics and science

(Young et al., 2011) and exit level reading and mathematics (Scott, 2012). Furthermore,

female, male, and Hispanic students outperformed their counterparts in mathematics

(Bicer et al., 2015; Erdogan, 2014; Wiswall et al., 2014), science (Erdogan, 2014;

Wiswall et al., 2014), and reading (Bicer et al., 2015; Erdogan, 2014). African American

students in STEM schools also performed better than their peers in non-STEM schools

for mathematics and science subjects (Wiswall et al., 2014). Economically

disadvantaged students scored higher than their counterparts in mathematics (Bicer et al.,

2015; Erdogan, 2014). However, STEM schools showed no significant difference in

traditional subjects in other studies (Bicer et al., 2014, 2015; Erdogan, 2014; Philips,

2013; Wiswall, 2014). Even though in some studies students in STEM schools

performed similar to non-STEM students, none of the studies showed the superiority of

non-STEM schools in any subjects.

The 1990s and Millennium Century Schools in Texas

Two types of schools attracted the attention of the public at the end of the 20th

and beginning of 21st century in the U.S. Charter schools and STEM schools were

popular during these years in the U.S. Texas was one of the states that offered these two

types of schools. The first charter schools opened in 1996 (Gronberg & Jansen, 2005) and STEM schools opened in 2006 (Avery, 2010) in the state of Texas. The total number of charter high schools and STEM schools (including T-STEM/Early college high schools) were 227 and 65 in Texas by the end of 2013, respectively.

Texas Charter Schools

From their inception, charter schools were classified into four groups in Texas: (1) home-rule district, (2) district (or campus), (3) open-enrollment, and (4) university or college (TEA, 2015). However, home-rule district charter schools are not currently in operation, and are schools in the district that operates under a home-rule charter (Taylor et al., 2011; TEA, 2015; TEC, 1995). District charter schools could be established at the request of the majority of the teachers and parents to convert an existing traditional public school, or governing body of a school district can establish a new school as a charter school within the boundaries of the school district (Taylor et al., 2011). Open-enrollment charter schools are created by non-profit charter operators (TEA, 2015). The university or college charter schools are an open-enrollment charter schools operated by universities or colleges located in Texas (Salinas, 2013).

T-STEM Academies

STEM schools at the state of Texas were called Texas STEM (T-STEM) academies. T-STEM academies were inclusive STEM schools. Inclusive STEM schools were open-enrolment schools that do not require specific criteria to accept students such as high grade point average. The logic behind the inclusive STEM schools was to increase students' interest and success in STEM disciplines rather than choosing already

interested students (i.e., gifted and talented) as selective STEM schools do. Therefore, to access all students and maintain equity in STEM, economically disadvantaged and underrepresented groups of students were encouraged to attend T-STEM academies. To have more than 50% of students who are economically disadvantaged or from a minority group was an obligation for T-STEM academies.

There are two types of T-STEM academies: school-within-a-school and stand-alone. School-within-a-school type of T-STEM academies included a subset of students enrolled in the STEM part of the school where as all students in stand-alone T-STEM academies were enrolled in a STEM program (S. Avery, personal communication, January 8, 2014).

Similarities and Differences Between Charter Schools and T-STEM Academies

Charter schools and T-STEM academies had some similarities and differences. They both had specific purposes and some of the goals were similar. For instance, both schools aimed to enhance students' learning (Texas Education Code [TEC], 2001) but T-STEM academies purposefully focused on S-T-E-M achievement (Avery, 2010; Texas Administrative Code [TAC], 2011). In addition, charter schools and T-STEM academies focused on providing innovative teaching and learning methods (TAC, 2011; TEC, 2001). The two models differed in some aspects. Charter schools were mainly created to offer an alternative to traditional public schools. To offer alternative school to the public, charter schools' goal focused on increasing the number of choice, providing new opportunities to attract new teachers to the system, and including a new form of accountability (Taylor et al., 2011; TEC, 2011). However, T-STEM academies main

goal was to focus on STEM education to educate future STEM workers. Thus, T-STEM academies different purposes than charter schools were: (a) increase the number of students who pursue STEM careers and degrees (TAC, 2011), (b) improvement of teachers' knowledge and skills by professional development, and (c) encouragement of school leadership (Educate Texas, 2013b). Even though charter schools and T-STEM academies met on a common ground at some point, they had differences in their goals.

Texas charter schools and STEM schools also had some differences in terms of their design. T-STEM Academy Design Blueprint (ADB) was a specific framework to establish and maintain the excellence in schools (Avery, Chambliss, Pruiett, & Stotts, 2010; TAC, 2011) and that provided superiority to T-STEM academies compared to charter schools. This blueprint had seven benchmarks. T-STEM ADB's seven benchmarks were: (1) mission-driven leadership, (2) T-STEM culture, (3) student outreach, recruitment, and retention, (4) teacher selection, development and retention, (5) curriculum, instruction, and assessment, (6) strategic alliances, and (7) academy advancement and sustainability. These benchmarks were suggested and required to provide well-structured T-STEM school. Researchers indicated that there were important components to have a well-structured STEM school (Erdogan, 2014; Marshall, 2010; Means, Confrey, House, & Bhanot, 2008; Means, House, Young, Wang, & Lynch, 2013; Peters-Burton, Lynch, Behrend, & Means, 2014; Subotnik, Tai, & Rickoff et al., 2009). These components were: (a) STEM mission, (b) administration, (c) informal learning environment, (d) formal learning environment, (e) teachers, (d) STEM specialists, (e) community partners, (f) STEM-curriculum, (g) research-based instruction, (h) advance

coursework, (i) assessments, and (j) outcome. T-STEM ADB established a replicable set of criteria for a well-structured T-STEM school environment. It included all the components suggested from the literature. The T-STEM ADB was the critical difference between charter schools and T-STEM academies. Therefore, one might expect that T-STEM academies' students would outperform charter schools' students in terms of STEM achievement as well as this would be the possibility of transformation of charter schools to T-STEM academies.

Methodology

A quasi-experimental design was used to examine students' achievement in reading, mathematics, and science over time in two types of charter schools, T-STEM academies or regular charter schools. The quasi-experimental design included a control group (i.e., non-T-STEM charter schools) and treatment (i.e., T-STEM academies) groups and up to three observations, depending on content, on which the groups were matched to determine the effect of intervention over time. Two types of datasets, student and school, were used to determine participants who were enrolled in two types of schools. Both data sets were obtained from TEA through Academic Excellence Indicator System and Public Information Request system. Students and school datasets included school level and student level variables, respectively. In this study, propensity score matching was used to determine participants from non-T-STEM charter schools in Texas. Hierarchical linear modeling was used to analyze students' achievement in three subjects over time.

Participants

Participants were (N_{total}=1481) enrolled in T-STEM academies and non-T-STEM charter schools in 2010-11, 2011-12, and 2012-13 academic years. Based in the demographics of schools, 825 (55.7%) students were female. According to the ethnicity breakdown, the majority of students were Hispanic (n= 1125, 76%). There were 123 Asian (8.3 %), 190 White (12.8%), and 43 African American (2.9%) students. 68.5% (n=1015) of students were classified as economically disadvantaged. TEA's definition of economically disadvantaged was a student eligible for free or reduced-price meals under National School Lunch and Child Nutrition Program (TEA, 2009). In addition, 2.3% of students were limited English proficient and 20.6% were categorized as "at-risk", who did not perform satisfactorily under defined criteria by TEA (2009).

There were two combinations of T-STEM academies in 2011. There were 21 T-STEM academies that also were charter schools but only 19 of them were stand-alone campuses. Two of the schools were school-within-a school model where there are students who receive the benefits of the T-STEM model and students who do not. Therefore, stand-alone campuses were the only ones of interest because data cannot be disaggregated within a school to partition non-T-STEM student performance from T-STEM student performance. As a result, only stand-alone T-STEM academies were used in this study. However, student data were only available from the dataset obtained from the TEA for 15 out of 19 stand-alone T-STEM campuses.

Propensity score matching was used to determine comparable non-T-STEM charter schools. Because of the nature of matching it was not possible to determine for

which campuses data would be available. That is schools were matched based on school characteristics that did not include actual student scores. It was possible to lose campuses after matching because data may not be available from TEA. Only Texas charter schools that served high school students were used for matching. After eliminating T-STEM charter schools, 227 remained. 15 T-STEM academies were matched to 30 charter schools but data for only 29 of them were available from the dataset obtained from TEA.

The number of participants in three academic subjects differed because some students did not have scores from all three academic subjects. Because of the nature of a longitudinal dataset, at least two time-points were required. Therefore, students who did not have scores for at least two years were excluded. There were 14 T-STEM academies and 18 non-T-STEM charter schools in the student dataset after the elimination of students. The number of students at each grade level who had two or three data points were reported to show the similarity of sample size in each academic subjects (see Table 15). For example, in reading there were 266 students who only had scores in 9th and 10th grades. There were 269 students who had scores in 10th and 11th grades, and 933 students who had scores for all three grades. Science was problematic because it was only tested in grades 10 and 11 so students who missed one assessment were lost to the study.

Table 15

Participants in T-STEM Charter and Non-T-STEM Charter Schools for Three Academic

Subjects by Grade Levels

Academic subject	Grade levels	N	N_{total}
Reading	9th & 10th	266	
	10th & 11th	269	
	9th, 10th & 11th	933	1468
Mathematics	9th & 10th	260	
	10th & 11th	274	
	9th, 10th & 11th	933	1467
Science	10th & 11th	1105	1105

For student level analysis several variables were used. Students' gender, socioeconomic status (SES) (i.e., whether classified as economically disadvantaged), at-risk status, and ethnicity were independent variables. In addition to that, a dichotomous variable (i.e., 1 indicated TSTEM and 0 indicated non-T-STEM charter) was used to identify whether a school was either a TSTEM charter academy or non-T-STEM charter school. Two additional variables were developed. Time and time-square variables were added and used to determine whether there was a linear or a quadratic growth over time. For the variable time, 0 indicated intercept (i.e., 2011), 1 indicated year 2 (i.e., 2012), and 2 indicated year 3 (i.e., 2013). The variable time-square was computed by squaring the time variable. Students' reading, mathematics, and science Texas Assessment

Knowledge and Skills (TAKS) scale scores were used as continuous dependent variables.

Estimation of Student Learning

Students' high-stake test scores were used to determine students' academic achievement. In the state of Texas, the high-stakes test was TAKS until 2012 (TEA & Pearson, 2013). In 2012, a new test was inaugurated. The State of Texas Assessments of Academic Readiness (STARR) was first administered to 9th graders and each year the subsequent grade level was added. For instance, in 2011, all students in ninth through eleventh grade were tested with TAKS. In 2012, ninth graders were tested with STAAR, 10th-11th graders were tested with TAKS. In 2013, 9th and 10th grade students took STARR, and 11th grade students took TAKS test. The nature of STARR test was not applicable for longitudinal examination because it was an end of course exam. However, because the TAKS test was given at the end of every spring semester, it was appropriate to use to determine students' change over time. The latest longitudinal examination of students in Texas would be from 2011 to 2013 for ninth trough eleventh grade students. Therefore, in this study, students' ninth grade TAKS scores in 2010-11, tenth grade TAKS scores in 2011-12, and eleventh grade TAKS scores in 2012-13 were used.

It is important to report the reliability of an instrument prior to its use. Therefore, the reliability estimates provided by TEA were reported for this study. Reliability or internal consistency is the average correlation among items in the test (Nunnally, 1967). The reliability coefficients for the TAKS test for each academic subject were released each year. Reliability coefficients for reading and mathematics were: (a) 0.87 and 0.92 in

2011, (b) 0.88 and 0.92 in 2012, and (c) 0.85 and 0.90 in 2013, respectively. For science

the reliability coefficient was 0.90 and 0.85 in 2012 and 2013, respectively (TEA &

Pearson, 2011, 2013, 2014).

Propensity Score Matching

In social science, the analysis of naturally occurring groups that were not

randomly assigned is common (Beal & Kupzyk, 2014). In this situation, inferences about

differences in dependent variables between two groups would be biased because this

difference might be attributable to group membership (Austin, 2011; Beal & Kupzyk,

2014). In addition, longitudinal studies are more powerful when a control group is

involved in the study but longitudinal quasi-experiments are not randomized (Holmes,

2014). Therefore, to limit bias due to group membership and to include a control group,

there is a need for a matching technique. Therefore, propensity score matching (PSM)

was used. Using PSM aids researchers in selecting control groups by matching on all

salient variables (Shadish & Steiner, 2010; Thoemmes & Kim, 2011).

Matching two groups (i.e., treatment and control) was conducted by using

propensity scores. Propensity scores were the probability of the participant to be

assigned to the treatment group by the set of observed covariates (Rosenbaum & Rubin,

1983). The main reason to use propensity score matching strategy was to mimic a

randomized design (Beal & Kupzyk, 2014), thus making comparisons about differences

in groups using covariates would be possible. Even though using covariates does not

control all differences, propensity scores improve the internal validity of between group

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comparisons (Holmes, 2014) and reduce the likelihood of internal threats (Guo & Fraser, 2010).

After the estimation of propensity scores, the matching method was another step. In this study, one-to-many matching was used. One-to-many matching was one of the commonly used matching methods after one-to-one matching (Thoemmes & Kim, 2011) (e.g., Capraro, Capraro, Morgan, Scheurich et al., 2015; Oner & Capraro, 2015). The advantage of one-to-many matching was to increase statistical power compared to one-to-one matching (Shadish & Steiner, 2010). In this study one-to-two matching was used because of the availability of the adequate matches (Thoemmes & Kim, 2011), which was another important issue that one needs to consider.

The propensity score matching was conducted using R version 2.14.0. 15 T-STEM academies (i.e., the treatment group) were matched to 30 non-T-STEM charter schools. In the matching, the percentage of mobility, English proficiency (LEP), SES, at-risk, African American, Hispanic and White students were used from the school dataset. The mean percentage of T-STEM academies and regular charter schools before and after matching were shown in Table 16.

Table 16

Unmatched and Matched Treatment and Control Group Means

	Unmatched		Matched	
Variables	T-STEM	Charter Schools	T-STEM	Charter Schools
	Mean	Mean	Mean	Mean
Mobility	13.07	56.90	13.07	13.22
African American	8.24	18.21	8.24	7.66
SES	64.80	70.21	64.80	64.08
Hispanic	68.16	50.33	68.16	68.08
LEP	9.02	9.43	9.02	10.13
At-risk	40.09	73.67	40.09	39.33
White	15.31	27.41	15.31	14.90

Figure 5 showed the distribution of propensity scores of matched treatment and control units besides unmatched control units. In this figure, it was possible to see how close each treatment unit matched to control units. The figure also showed that using more than 1:2 ratio would not be appropriate, because other unmatched control units were pooled to one side.
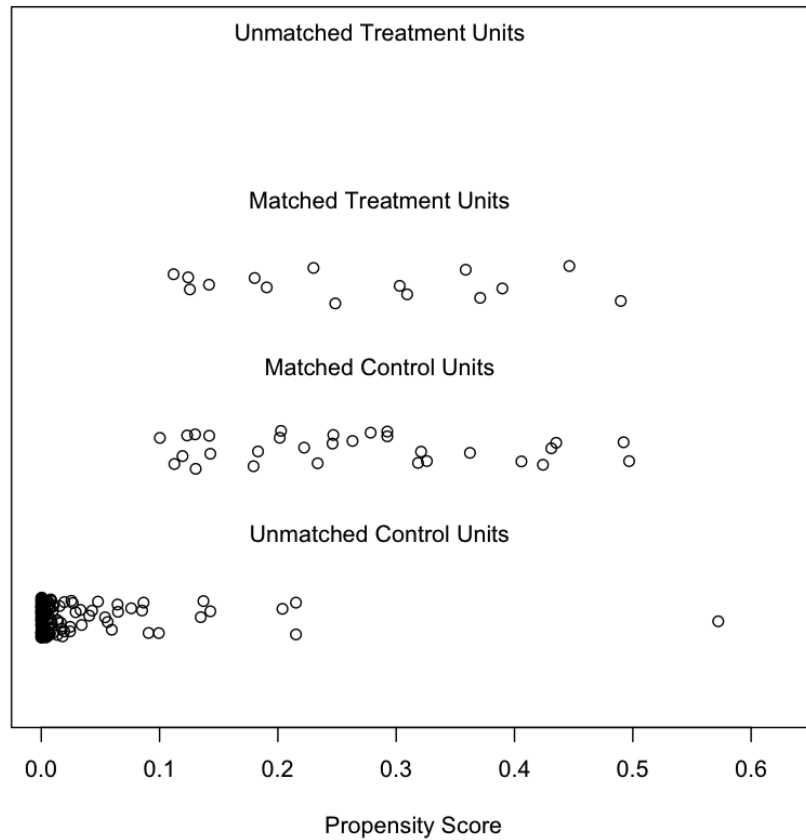
Figure 5. Distribution of propensity scores

Data Analysis

Individuals' knowledge and skills change over time has been an important phenomenon of interest in educational studies (Bryk & Raudenbush, 1988). The aim of this study was to understand students' academic achievement growth through high school in two different groups of schools (i.e., T-STEM charter and non-T-STEM charter schools). Students' learning took place in schools and schools' characteristics can have substantial influence on their learning process (Bryk & Raudenbush, 1988). The data had nested structures: (1) because of students' repeated measures and (2)

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students within schools. Therefore, in this study, hierarchical linear modeling (HLM) as a multilevel analysis was used to examine the data.

When data has a nested structure, observations are usually not independent because the observations are clustered showing more similar characteristics rather than randomly sampled observations (Garson, 2013). To avoid the violation of independence of observations, HLM could be used (Hox, 2002; Raudenbush & Bryk, 2002). In addition, HLM is useful to analyze longitudinal data and is capable of dealing with unbalanced data structures (Snijders & Bosker, 1999). Thus, a three level HLM was used to analyze students' academic achievement over 3 years. Level-1 included students' repeated measures. Level 2 had student variables nested within schools. Level 3 had school types (T-STEM charter or non-T-STEM charter school).

The first model, fully unconditional, with scores nested within students, and students nested within schools was analyzed to determine whether the data was appropriate for higher levels (Raudenbush & Bryk, 2002). The reading, mathematics, and science scores were labeled ACHIEVEMENT in every model to keep the models generic. The first model equations by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + e_{ijk}$
Level 2 Equation: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
Level 3 Equation: $\beta_{00k} = \gamma_{000} + u_{00k}$

The formula $\rho = \tau_\beta / \tau_\pi + \tau_\beta$ was used to represent proportion of variance between schools, where τ_π is level-2 variance, and τ_β is level-3 variance (Raudenbush & Bryk, 2002).

The second model included time variable that indicates the time point. The second model by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + e_{ijk}$
Level 2 Equations: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
$\qquad\qquad\qquad \pi_{1jk} = \beta_{10k} + r_{1jk}$
Level 3 Equations: $\beta_{00k} = \gamma_{000} + u_{00k}$
$\qquad\qquad\qquad \beta_{10k} = \gamma_{100} + u_{10k}$
Because there were three time points, quadratic growth was also taken into

consideration.

The third model included timesq variable. However this variable was not added

to the model in science because the test was administered for only two years in science.

The third model (i.e., only for mathematics and reading achievement) by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + \pi_{2jk}*(TIMESQ_{ijk}) + e_{ijk}$
Level-2 Equation: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
$\qquad\qquad\qquad \pi_{1jk} = \beta_{10k} + r_{1jk}$
$\qquad\qquad\qquad \pi_{2jk} = \beta_{20k}$
Level-3 Equation: $\beta_{00k} = \gamma_{000} + u_{00k}$
$\qquad\qquad\qquad \beta_{10k} = \gamma_{100} + u_{10k}$
$\qquad\qquad\qquad \beta_{20k} = \gamma_{200}$
In the fourth model, the TSTEM variable was added to level-3 equations. This

variable helped to determine how much variance was explained by a school being T-

STEM charter or non-T-STEM charter. Because the research question relied on the

examination of the difference of students' academic achivement over time in two

different school types (i.e., T-STEM charter or non-T-STEM charter), addition of

TSTEM variable had priority then student level time-invariant covariates. The fourth

model by levels were:

Level 1 Equation: $ACHIEVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + \pi_{2jk}*(TIMESQ_{ijk}) + e_{ijk}$
Level-2 Equation: $\pi_{0jk} = \beta_{00k} + r_{0jk}$
$\qquad\qquad\qquad \pi_{1jk} = \beta_{10k} + r_{1jk}$
$\qquad\qquad\qquad \pi_{2jk} = \beta_{20k}$
Level-3 Equation: $\beta_{00k} = \gamma_{000} + \gamma_{001}(TSTEM_k) + u_{00k}$
$\qquad\qquad\qquad \beta_{10k} = \gamma_{100} + \gamma_{101}(TSTEM_k) + u_{10k}$
$\qquad\qquad\qquad \beta_{20k} = \gamma_{200} + \gamma_{201}(TSTEM_k)$

In the final model, student level covariates were added. The student level variables were gender, SES, at-risk status, and ethnicity. In terms of ethinicity, 76% of students were Hispanic. In addition, the 96% of Hispanic students were economically disadvanaged. The correlation coeffieicient of being economically disadvantaged and hispanic was 0.7. The distribution of students' ethinicity and four categories of economically disadvantaged status (i.e., non-economically disadvantaged, free lunch, reduced lunch, and other economically disadvantaged) were shown in Table 17. Thefore, in the analysis, instead of SES variable, only ethnicity variable was added to the model to represent both covariates' charasterictis.

Table 17

Cross Distribution of Ethnicity and Economically Disadvanaged Status

	Economically Disadvantaged Status				
Ethnicity	Non-ED**	Free Lunch	Reduced Lunch	Other ED**	Total
Asian	106	14	3	0	123
AA*	25	17	1	0	43
Hispanic	148	876	68	33	1125
White	187	3	0	0	190
Total	466	910	72	33	1481

*AA: African American
**ED: Economically Disadvantaged

The variable etnicity was recoded and White students were selected as the reference group. African American (i.e., ETH_B), Asian (i.e., ETH_A), and Hispanic (i.e., ETH_H) students were dummy coded in the dataset. The final model's level-2 equations were:

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}*(ETH\_A_{jk}) + \beta_{02k}*(ETH\_B_{jk}) + \beta_{03k}*(ETH\_H_{jk}) + \beta_{04k}*(ATRISK_{jk}) + \beta_{05k}*(GENDER_{jk}) + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k} + \beta_{11k}*(ETH\_A_{jk}) + \beta_{12k}*(ETH\_B_{jk}) + \beta_{13k}*(ETH\_H_{jk}) + \beta_{14k}*(ATRISK_{jk}) + \beta_{15k}*(GENDER_{jk}) + r_{1jk}$$

$$\pi_{2jk} = \beta_{20k} + \beta_{21k}*(ETH\_A_{jk}) + \beta_{22k}*(ETH\_B_{jk}) + \beta_{23k}*(ETH\_H_{jk}) + \beta_{24k}*(ATRISK_{jk}) + \beta_{25k}*(GENDER_{jk})$$

In the final model TSTEM and student level covariates interaction effects were taken into account to examine the specific group of students' performance in T-STEM charter schools.

In this study, full maximum likelihood (FML) was used as an estimation method. When sample sizes are not equal across groups FML provides more robust estimates (Garson, 2013). In this study, the sample size for each group was not equal; therefore, it was unbalanced. Full maximum likelihood is an estimation theory for three level models (Raudenbush & Bryk, 2002) and it is also the default in HLM 7 for three level models.

Process for accounting for time. For quadratic growth, the growth rate at each year can be computeed by using the derivate of the level 1 equation. For instance, $ACHIVEMENT_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + \pi_{2jk}*(TIMESQ_{ijk}) + e_{ijk}$, the average growth rate at the end of the second year (i.e., 2012) for mathematics and reading would be $t = \pi_{1jk} + 2*\pi_{2jk}*(2012\text{-}2011)$ (cf., Raudenbush & Bryk, 2002).

Results

Key Features of the Data

Descriptives statistics for all students' scores in mathematics, reading and science for the baseline year (i.e., 2011 for mathematics and reading, 2012 for science) were represented in Table 3. Mean and standard deviation were reported by gender, ethnicity, and at-risk status (see Table 18). According to the mean scores, male students had higher scores than female students in mathematics and science, whereas, female students outperformed in reading. Not at-risk students' scores were higher than at-risk students in three academic subjects. In terms of ethnicity, Asian students scored higher than other students in three academic subjects. Black students' scores were higher than White students in reading and science. White students outperformed Hispanic students in reading and science. In mathematics, the score ranking from highest to the lowest in terms of ethnicity was Asian, White, Hispanic, and Black, respectively (e.g., Capraro, Young, Lewis, Yetkiner, & Woods, 2009).

Table 18

Students' Scores in Mathematics, Reading, and Science in the Baseline Year

Variable	Category	Mathematics		Reading		Science	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Gender	Female	2353.73	230.73	2382.71	238.31	2279.44	155.67
	Male	2371.30	242.81	2363.11	202.16	2331.17	158.48
At-risk	At-risk	2284.59	254.56	2303.71	254.21	2251.23	176.39
status	Not at-risk	2384.48	225.52	2395.03	208.58	2315.35	151.88
	Asian	2478.69	240.47	2438.01	251.99	2371.66	154.71
	AA*	2285.14	182.81	2431.19	232.74	2339.13	170.15
Ethnicity	Hispanic	2348.36	220.27	2361.19	204.44	2289.36	158.51
	White	2381.97	304.02	2391.40	287.54	2328.49	148.94

*AA: African American

Descriptive statistics indicated the trajectory of all students' scores in three academic subjects (see Table 19). In mathematics and reading, all students' scores showed positive parabolic trajectory. In science, students' scores increased over time.

Table 19

Students' Mean Score and Standard Deviations in Academic Subjects for Three Years

Year	Mathematics		Reading		Science	
	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$	*SD*
2011	2361.48	236.20	2374.14	223.14		
2012	2293.11	167.57	2319.52	129.49	2302.76	158.97
2013	2365.31	172.02	2349.36	147.54	2334.41	134.80

The 95% confidence intervals (CI) for the mean of each academic subject for T-STEM charter and non-T-STEM charter schools were computed (see Figure 6, 7, and 8). For reading, mathematics, and science, students' mean sccores in non-T-STEM charter schools were higher than their counterparts. Students' mathematics achivement for two groups of schools showed the same trend. Their mean scores in 2011 was greater than their second year mean score (i.e., 10th grade [2012]). There was an increase in both groups' mean mathematics scores from 2012 to 2013. T-STEM charter schools' third year mean score was greater than their baseline score but not so for non-T-STEM charter schools. In addition, from years 2011 to 2012, non-T-STEM charter schools had a greater rate of change than did T-STEM charter schools. From second to third year, T-STEM charter schools had greater rate of change than did non-T-STEM charter schools (see Figure 6).
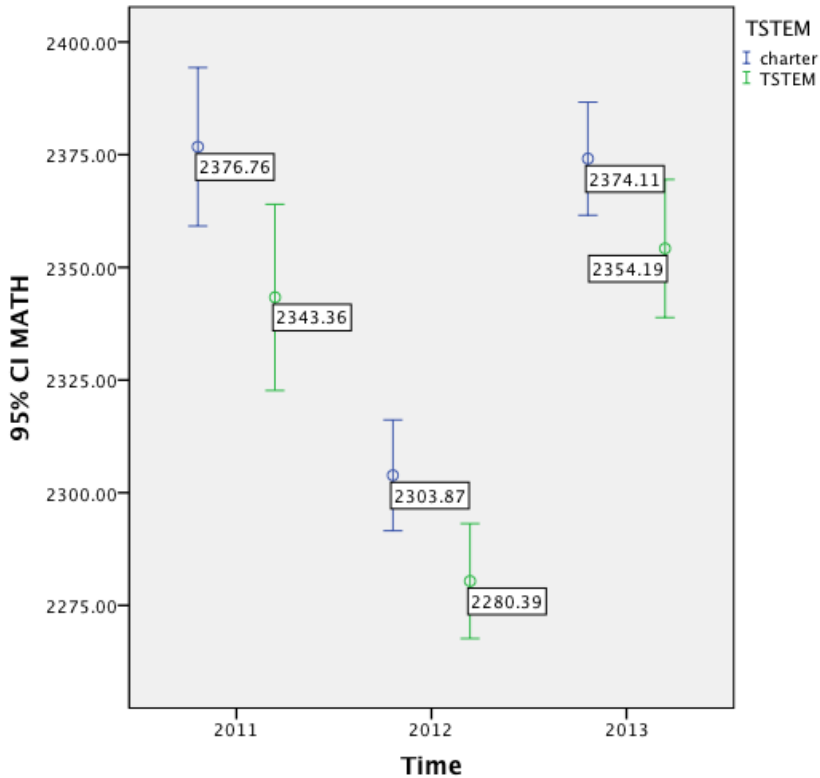
Figure 6. 95% CI for mean of mathematics achievement for T-STEM and non-T-STEM
charter schools in three years

In reading, a similar trend was observed across years as in mathematics.
Regardless of the year, the mean for T-STEM charter schools was always lower than that
of non-T-STEM charter schools. For both groups, their third year mean was lower than
their baseline score. The differences in baseline scores were still present in year three.
Therefore, T-STEM charter schools did not close the gap in reading. In addition, in
mathematics and reading, both for T-STEM charter and non-T-STEM charter schools'

CIs for first years were wider than other years. This implied that schools' first year

estimates were less precise than their second and third years (Thompson, 2006).
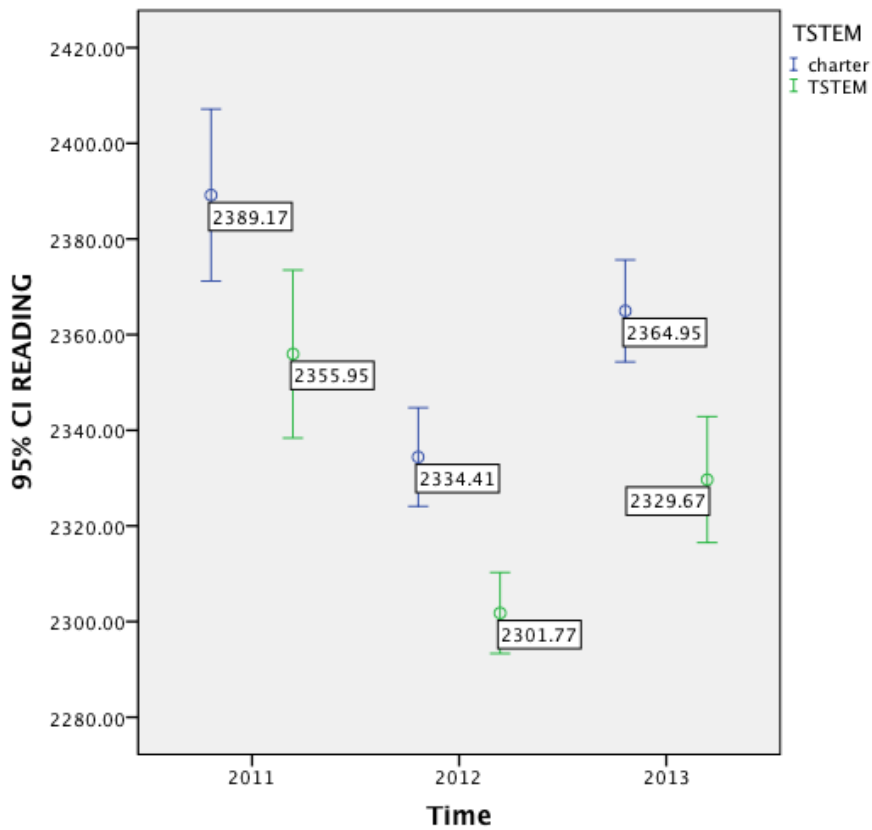
Figure 7. 95% CI for mean of mathematics reading for T-STEM and non-T-STEM

charter schools in three years

Similar to mathematics and reading's pattern, T-STEM charter schools' means were lower than non-T-STEM charter schools in science for both years. For both groups, the 95% CIs for the means showed that there was a statistically significant difference between schools' first year and second year mean scores. However, the slope for T-STEM charter schools was steeper than non-T-STEM charter schools, which indicated that T-STEM charter schools were making some gains in performance (see Figure 8).
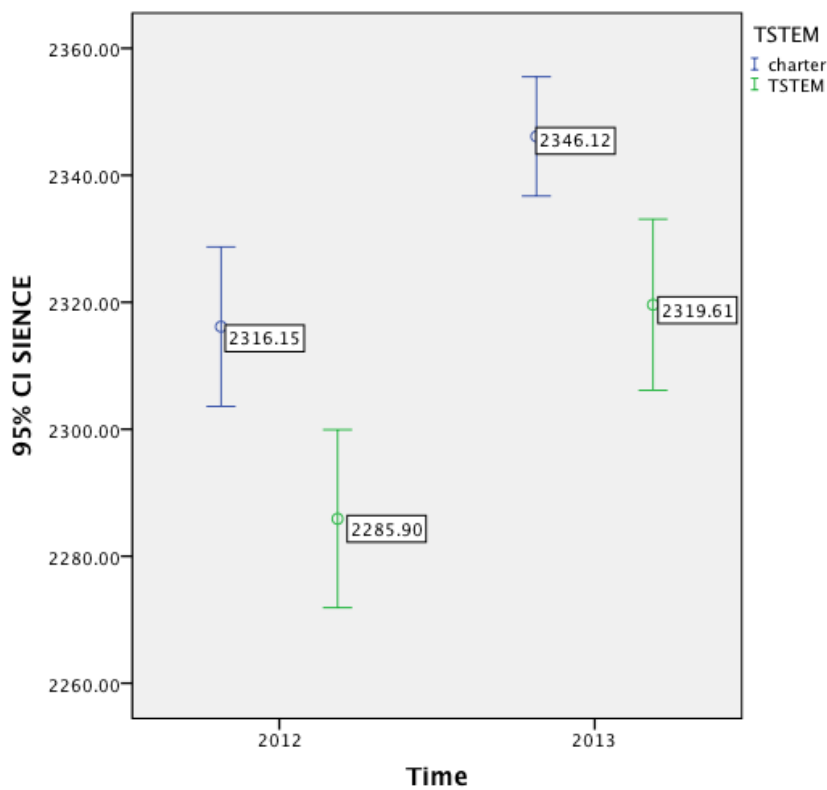
Figure 8. 95% CI for mean of science achievement for T-STEM and non-T-STEM charter schools in two years

HLM Analyses

The longitudinal data was analyzed using HLM 7 software. Three-level HLM was used to investigate students' mathematics, reading , and science achievement in T-STEM charter and non-T-STEM charter schools over time. The unconditinal model explored how much of the variation in outcome variable was within and between schools.

Unconditional model. The grand mean (γ_{000}), the estimated within-school variance (τ_π), and between-school variance (τ_β) were shown in Table 20 for each academic subject. According to the unconditional model, 83% of the variation in the mathematics achievement was within schools whereas 17% was between schools. 78% of the variation in the reading was within schools and 22% was between schools. In science, the within school variation was 86% and between school variation was 14%.

Table 20

Grand Mean, Within and Between School Variance for Mathematics, Reading, and Science Scores

Subject	Grand mean	Within-school variance (τ_π)	Between-school variance (τ_β)
Mathematics	2326.18	19900.58	4043.52
Reading	2338.30	9012.83	2517.07
Science	2312.94	10887.21	1762.33

The final model. The fourth model included student level and school level variables. The results of HLM analysis were represented in Table 21 for three academic subjects. The main effects of time ($p<0.001$), timesq ($p<0.001$), at-risk ($p<0.001$), and gender ($p=0.01$) were statistically significant in the first year for mathematics. The interaction effects for students' mathematics scores were statistically significant: (1) TSTEM ×Hispanic ($p<0.03$), (2) TSTEM × at-risk ($p =0.03$), (3) time× TSTEM ($p =0.009$), (4) time × TSTEM × Asian ($p =0.007$), (5) time × TSTEM × Hispanic ($p <0.001$), (6) time × TSTEM × at-risk ($p =0.02$), (7) timesq × TSTEM ($p =0.01$), (8) timesq × TSTEM × Asian ($p =0.02$), (9) timesq × TSTEM × African American ($p =0.03$), and (10) timesq × TSTEM × Hispanic ($p =0.003$). The main effects of time ($p=0.007$), timesq ($p=0.01$), TSTEM ($p=0.03$), at-risk ($p=0.003$), and Hispanic ($p=0.03$) were statistically significant in the initial year for reading. The interaction effects for reading scores of students were statistically significant: (1) TSTEM ×Hispanic ($p=0.002$), (2) TSTEM × at-risk ($p=0.008$), (3) time × TSTEM × at-risk ($p=0.02$), (4) time × TSTEM × gender ($p=0.03$), (5) time × TSTEM × Hispanic ($p=0.01$), (6) time × gender ($p=0.001$), and (7) timesq × gender ($p=0.01$). The main effects of gender ($p<0.001$) and at-risk ($p<0.001$)were statistically significant in the initial year for science. The interaction effect for African American with TSTEM and time ($p=0.01$) was statistically significant in science (see Table 21).

The γ_{000} coefficient represented the predicted initial year of White, not at-risk female student in a non-T-STEM charter school (i.e., reference student). For such as

student in the predicted mathematics (reading, and science) achievement was 2407.65 (2428.01 and 2314.04). On average, such students in T-STEM charter schools scored 84.16, 86.61, and 17.45 points lower than students in non-T-STEM charter schools in mathematics (M), reading (R), and science (S), respectively. If student was an Asian, not at-risk female, the average score increased 58.45 (M), 29.79 (R), and 22.62 (S) points; if the student was an African American not at-risk female, the average score decreased 79.32 (M) and increased 49.38 (R) and 83.54 (S); and if the student was Hispanic, not at-risk female, the average score decreased 62.29 (M), 57.72 (R), and 22.84 (S) points. However, for an Asian, not at-risk female student in a T-STEM charter school, on average the mathematics, reading, and science achivement increased 75.28, 29.79, and 22.62 points; if the student was an African American, not at-risk female in a T-STEM charter school, average mathematics and reading achivement decreased 84.26 and 79.44, points wherease increased 1.8 points for science; and if the student was Hispanic, not at-risk female in a T-STEM charter school, average mathematics, reading, and science achivement decreased 27.36, -23.24, and -56.99 points. For a White, not at-risk male students in a non-T-STEM charter school, the initial average mathematics, reading, and science scores were 2447.48, 2433.07, and 2368.94. However, for White, not at-risk male students in a charter school, the average mathematics and reading scores decreased 87.23 and 116.37 points whereas increased 42.06 points for science. A typical White, at-risk female student in a non-T-STEM charter school scored 2297.65 (M), 2366.95 (R), and 2222.68 (S) on average; however such students scored 162.6 (M), 164.11 (R), and

1.52 (S) points lower in a T-STEM charter school in mathematics, reading, and science, respectively.

The predicted learning rate for the reference student group was -194.44, -81.93 and 19.15 for mathematics, reading, and science, respectively. On average, a reference group student's mathematics and reading scores decreased 194.44 and 81.93 points but their scicence score increased 19.15 points per academic year. However, on average, a T-STEM charter student's learning rate decreased 60.97 (M) and 30.51 (R) points, whereas the science learning rate increased 12 points per academic year. This showed that T-STEM charter schools average academic learning rate was 133.47 (M) and 51.42 (R) points higher than non-T-STEM charter schools per year. On average, Asian, not at-risk female students mathematics, reading, and science learning gain was 58.53, 69.79, and 34.58 points; for African American, not at-risk female students their learning rate decreased 19.30 (M), 76.46 (R), and 59.37 (S) points; for Hispanic, not at-risk female students their learning rate increased 87.10 (M), 22.74 (R), and 10.38 (S) points. On average, the learning rate increased 6.11 (M), 33.37 (R), and 11.2 (S) points for Asian, not at-risk female students in T-STEM charter schools. On average, the learning rate increased 29.26 (M), 32.15 (R) points whereas decreased 46.61 points in science for Hispanic, not at-risk female students in T-STEM charter schools. On average, for an African American, not at-risk female student in a T-STEM charter school, the learning rate gain was 162.66 (M) and 33.37 (R) points whereas the learning rate decreased 243.97 points in science. On average, the learning rate for a White, at-risk female student in a non-T-STEM charter school increased 1.03 (M), 12.39 (R), and 26.40 (S)

points. On average, for a White, at-risk female student in a T-STEM charter school, the mathematics and reading learning rate per academic year increased 218.88 and 154.26 points whereas decreased 19.08 points in science. On average, for a White, not at-risk male student in a non-T-STEM charter school, the learning gain per academic year was 0.52 (M) and the reading and science learning rate decreased 70.72 and 8.12 points. If student was a White, not at-risk male student in a T-STEM charter school, the average learning rate per academic year increased 165.42 (M) and 49.52 (R) points but decreased 20.74 points in science.

The mean accelaration was statistically significant ($p<0.001$) and positive (γ_{200}=86.96 and γ_{200}=32.92) in mathematics and reading. From the descriptive analysis, it was seen that schools growth was not linear for mathematics and reading performance. Therefore, there was a need for a variable (i.e., timesq) to estimate the accelaration rate of schools to examine their growth rate over time. At the end of the second year, the average growth rate for White, not at-risk female student in a non-T-STEM charter school was -20.52 (-194.44+2(86.96)1) (M) and -16.09 (R) points per year. For such students, by the end of the third year, the average growth rate had grown to 153.4 (M) and 49.75 (R) points per year. For a White, not at-risk female student in a T-STEM charter school, the average growth rate was 10.07 (M) and 5.45 (R) at the end of the second year. By the end of the third year, the average growth rate had grown to 81.11 (M) and 41.41 (R) points per year for a White, not at-risk female student in a T-STEM charter school.

The average growth rate for an Asian, not at-risk female student in a non-T-STEM charter school was 10.99 (M) and -9.09 (R) points per year by the end of the second year, whereas -36.55 (M) and -87.97 (R) points per year by the end of third year. The average growth rate for an Asian, not at-risk female student in T-STEM charter school was -34.94 (M) and -5.53 (R) points per year by the end of the second year, whereas 47.48 (M) and 6.99 (R) points per year by the end of third year.

The average growth rate for an African American, not at-risk female student in a non-T-STEM charter school was 39.56 (M) and -27.82 (R) points per year by the end of second year, whereas 98.42 (M) and 20.82 (R) points per year by the end of third year. However, for an African American, not at-risk female student in a T-STEM charter school, the average growth rate was -129.53 (M) and -137.63 (R) points per year by the end of second year, whereas -288.25 (M) and -223.19 (R) points per year by the end of third year.

The average growth rate for a Hispanic, not at-risk female student in a non-T-STEM charter school was 26.92 (M) and 18.76 (R) points per year by the end of second year, whereas -33.26 (M) and 14.78 (R) points per year by the end of third year. However, for a Hispanic, not at-risk female student in a T-STEM charter school, the average growth rate was -34.77 (M) and -27.23 (R) points per year by the end of second year, whereas 34.66 and 42.57 points per year by the end of third year.

The average growth rate for a White, at-risk female student in a non-T-STEM charter school was 0.95 (M) and 6.95 (R) points per year by the end of second year, whereas 0.87 (M) and 1.51 (R) points per year by the end of third year. The average

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growth rate for a White, at-risk female student in a T-STEM charter school was 103.27 (M) and 175.04 (R) points per year by the end of second year, whereas 121.13 (M) and 247.24 (R) points per year by the end of third year. The average growth rate for a White, not at-risk male student in a non-T-STEM charter school was 1.46 (M) and -21.88 (R) points per year by the end of second year, whereas 2.40 (M) and 26.96 (R) points per year by the end of third year in mathematics and reading. However, for a White, not at-risk male student in a T-STEM charter school, the average growth rate was 25.19 (M) and -4.16 (R) points per year by the end of second year, whereas 18.43 (M) and -6.42 (R) points per year by the end of third year.

Discerning practical importance. There was statistically significant variation among students within schools for the initial year on mathematics, reading, and science scores. In addition, there was statistically significant variation on learning rate in mathematics and reading. The school variable (i.e., TSTEM) accounted for 45% and 7% of the variation in the initial year on reading and science, respectively. However for mathematics, school grouping (TSTEM) explained an unimportant amount of the variation in the initial year (0.6 %) and in the learning rate (0.1%). Each student level variable was added one at a time to estimate the variance accounted for by each variable until all variables had been added. All three ethnicity variables accounted for 3%, 1%, and 2% of the parameter variance in the initial year in science, reading, and mathematics, respectively. Ethnicity variables accounted for 3% and 0.5% of the parameter variance in growth rates for reading and mathematics. The variable gender explained 5%, 0.1%, and 0.4% variability in the initial year in science, reading, and

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mathematics, respectively, 1% and 2% of the parameter variance in growth rates for reading and science. Addition of at-risk variable accounted for 66%, 5%, and 7% of the variation in the initial year in science, reading, and mathematics, respectively, whereas 2% and 4% of the variation in growth rates for reading and mathematics.

Table 21

Effects of Student and School Level Variables on Students' Mathematics, Reading, and Science Achievement

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Intercept	2407.65*	38.84	61.98	2428.01*	25.54	95.05	2314.04*	21.53	107.43
TSTEM	-84.16	56.15	-1.49	-86.61*	38.47	-2.25	-17.45	33.82	-0.51
Asian	58.45	42.34	1.38	29.79	34.96	0.85	22.62	26.55	0.85
TSTEM × Asian	100.99	59.36	1.70	6.23	50.56	0.12	35.10	40.41	0.86
AA**	-79.32	55.98	-1.41	49.38	49.30	1.01	83.54	54.70	1.52
TSTEM × AA**	79.22	79.35	0.99	39.03	69.23	0.56	-145.53	82.46	-1.76
Hispanic	-62.29	39.15	-1.59	-57.72*	26.82	-2.15	-22.84	22.99	-0.99

(continued)

Table 21 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
TSTEM ×									
Hispanic	119.09*	54.82	2.17	121.09*	39.68	3.05	-16.92	35.48	-0.47
At-risk	-110.00*	26.85	-4.09	-61.05*	20.78	-2.93	-91.36*	19.71	-4.63
TSTEM × at-risk	-78.44*	36.25	-2.16	-77.50*	29.31	-2.64	15.93	26.40	0.60
Gender	39.83*	15.65	2.54	5.07	14.75	0.34	54.90*	11.24	4.88
TSTEM × gender	-42.90	23.15	-1.85	-34.83	22.01	-1.58	4.61	16.93	0.27
Time	-194.44*	30.26	-6.42	-81.93*	30.48	-2.68	19.15	13.62	1.40
Time × TSTEM	133.47*	47.47	2.81	51.42	48.77	1.05	-7.15	24.46	-0.29
Time × Asian	58.53	45.99	1.27	69.79	48.32	1.44	34.58	22.27	1.55

(continued)

Table 21 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Time × TSTEM ×									
Asian	-185.89*	68.22	-2.72	-87.84	72.25	-1.21	-16.23	35.43	-0.45
Time × AA**	-19.30	71.19	-0.27	-76.46	73.88	-1.03	-59.37	46.10	-1.28
Time × TSTEM ×									
AA**	48.49	99.21	0.48	24.39	104.18	0.23	-177.45*	73.80	-2.404
Time × Hispanic	87.10*	32.10	2.71	22.74	32.46	0.70	10.38	14.78	0.70
Time × TSTEM ×									
Hispanic	-191.31*	49.17	-3.89	-119.77*	50.78	-2.35	28.92	25.61	1.12
Time × at-risk	1.03	27.02	0.03	12.39	27.95	0.44	26.40	14.28	1.84

Table 21 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Time × TSTEM ×									
at-risk	84.38*	38.66	2.18	90.45*	40.61	2.22	-38.34	20.85	-1.83
Time × gender	0.52	20.55	0.02	-70.72*	22.20	-3.18	-8.12	10.77	-0.75
Time × TSTEM ×									
gender	31.43	30.59	1.02	68.82*	33.18	2.07	-5.47	16.21	-0.33
Timesq	86.96*	12.57	6.91	32.92*	13.43	2.45			
Timesq × TSTEM	-51.44*	20.91	-2.45	-14.94	22.37	-0.66			
Timesq × Asian	-23.77	20.15	-1.17	-39.44	21.62	-1.82			

(continued)

Table 21 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Timesq × TSTEM									
× Asian	67.48*	30.85	2.18	45.70	32.92	1.38			
Timesq × AA**	29.43	35.88	0.82	24.32	36.08	0.67			
Timesq × TSTEM									
× AA**	-108.79*	52.21	-2.08	-67.11	53.74	-1.24			
Timesq ×									
Hispanic	-30.09*	13.51	-2.22	-1.99	14.44	-0.13			
Timesq × TSTEM									
× Hispanic	64.81*	21.84	2.96	36.89	23.36	1.57			

(continued)

Table 21 (continued)

Fixed Effect	Mathematics			Reading			Science		
	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio	Coefficient	*SE*	*t*-ratio
Timesq × at-risk									
	-0.04	11.95	-0.01	-2.72	12.82	-0.21			
Timesq × TSTEM									
× at-risk	-8.89	17.44	-0.51	-33.38	18.71	-1.78			
Timesq × gender	0.47	9.42	0.05	24.42*	10.09	2.42			
Timesq × TSTEM									
× gender	-3.85	14.05	-0.27	-25.55	15.08	-1.69			

*p<0.05
**AA: African American

Conclusion

In this study, the reason of why many T-STEM academies were converted from charter schools was examined, whether the intention was to improve students' STEM achievement, by comparing students' academic performance in T-STEM charter and non-T-STEM charter schools. In the state of Texas, the percentage of stand-alone T-STEM charter schools was noteworthy to investigate compared to stand-alone non-charter T-STEM academies. In this study, T-STEM charter schools and non-T-STEM charter schools were examined in terms of students' mathematics, reading, and science achievement over time. This study is the first to examine two variations of charter schools. Therefore, it maintains the importance of being the only study to examined two types of charter schools that one being STEM school. Charter schools were compared to traditional schools in the literature (see Barr et al., 2006; CREDO, 2010, 2011, 2012; Gutierrez, 2012; Pardo, 2013; Rose 2013; Tuttle et al., 2010, 2013; Woodworth et al., 2008) as well as STEM schools to traditional public schools (see Bicer et al., 2015; Erdogan, 2014; Means et al., 2014; Oner, 2015; Oner & Capraro, 2015; Philips, 2013; Wiswall et al., 2014; Young et al., 2011). However this study fills the gap in the literature in terms of investigating charter schools as they transform into a T-STEM academy.

The results for mathematics performance of T-STEM charter and non-T-STEM charter schools were mixed. T-STEM charter schools and non-T-STEM charter schools differed over time in terms of mathematics achievement. T-STEM charter schools showed a positive continuous increase over time, whereas non-T-STEM charter schools

initially decreased in 2012 but then increased in 2013. When student demographics was taken into account, the results for T-STEM charter schools were not promising, but for two groups of students; Asian and Hispanic. For Asian and Hispanic students, T-STEM charter schools showed positive parabolic trajectory, which was not the case for non-T-STEM charter schools. T-STEM charter students started more disadvantaged as compared to their counterparts; however, it is encouraging that there were more positive results for economically disadvantaged Hispanic students. This finding reveals that T-STEM charter schools are successful with Hispanic and economically disadvantaged students with regard to mathematics achievement.

Reading achievement was more favorable for students in non-T-STEM charter schools as compared to T-STEM charter schools. Over time, however, both schools failed to show positive growth for male, African American, or at-risk students. However, there was an encouraging results for Hispanic and Asian students over time for both schools.

The findings highlighted the fact that both schools types were mostly ineffective for improving science achievement except for female Asian and Female Hispanics. The results were troubling, showing a linear decrease for males, African Americans, and at-risk students. Hispanic students in T-STEM charter schools had achievement than their counterparts in non-T-STEM charter schools. This result is promising in terms of reaching the desired goal of T-STEM charter school to increase minority student access to post secondary opportunities.

The current study highlights the importance of STEM designation on a specific group of students. Hispanic, economically disadvantaged students in T-STEM charter schools showed positive growth over time. T-STEM academies are obligated to serve minority and economically disadvantaged students (Young et al., 2011). Seventy-six percent of the participants were Hispanic and 96% of them were economically disadvantaged. This indicates that the funding and resources provided at T-STEM charter schools helps to (see Avery et al., 2010) improve the opportunities for a very important minority group.

CHAPTER V

THE EFFECTS OF STEM MIDDLE SCHOOL ON STEM HIGH SCHOOL
STUDENTS' ACHIEVEMENT

Introduction

Obtaining a science, technology, engineering, and mathematics (STEM) degree is a benefit for individuals' level of prosperity and to their standing in the community. First, the completion of a STEM degree increases the likelihood of being employed. In 2010, the unemployment rate for STEM occupations was 5.3% whereas it was almost 10% for non-STEM occupations (U.S. Department of Commerce Economics and Statistics Administration, 2011). Second, STEM graduates have the opportunities to obtain higher-paying jobs than their counterparts (U.S. Department of Commerce Economics and Statistics Administration, 2011; National Science Board [NSB], 2014). Salaries for STEM workers were 26% higher than their counterparts (U.S. Department of Commerce Economics and Statistics Administration, 2011). Third, STEM graduates who did not choose a STEM career path were still qualified to pursue a non-STEM related job (U.S. Department of Commerce Economics and Statistics Administration, 2011). Last, the development of science and technology, in the near term, will strengthen employment opportunities (Committee on Science, Engineering, and Public Policy, 2010). Although there are many bright opportunities for the prepared STEM graduate, student pursuing STEM majors is not as great as one might expect.

The number of students who entered STEM fields in college was small and the number of students who entered and continued to STEM disciplines has gotten smaller.

This showed that there was leak in the STEM pipeline (Blickenstaff, 2005; Capraro, 2013; Lee, 2011; Subotnik, Tai, & Rickoff et al., 2009; Xu, 2008). To prevent that leak, the number of students entered into STEM pipeline and their proficiency in these disciplines should be increased. The creation of STEM schools in the United States (U.S.) was one attempt to achieve this goal (PCAST, 2010; NRC, 2011a). To be successful on minimizing the leakage, students should be exposed to STEM activities at early ages because the results showed that having early experience increase students' interest and achievement in STEM disciplines (Brody, 2006). Therefore, in this study, the effectiveness of early experience in STEM subjects in STEM schools was examined.

Academic Factors on Students' STEM Attainment

Students' academic achievement is influential on their post-secondary STEM track. Research results demonstrated that students' achievement in high school predicts students STEM attainment. For instance, high school grade point average (GPA) was highly correlated with students' intentions to (1) pursue STEM majors (Griffith, 2010), (2) their freshman science course grade in college (Tai, Sadler, & Mintzes, 2006), and (3) their interest in STEM fields (Nicholls, Wolfe, Besterfield-Sacre, Shuman, & Larpkiattaworn, 2007). Students' Scholastic Aptitude Test (SAT) and specifically the mathematics subscale were predictive of choosing STEM majors (Griffith, 2010; Nicholls et al., 2007), college achievement (Tai, Sadler, & Mintzes, 2006), and changing their program to STEM (Crisp, Nora, & Taggart, 2009). High school students' mathematics scores (Tai, Sadler, & Mintzes, 2006), their mathematics ability (Nicholls et al., 2007), and advanced placement (AP) (Grififth, 2010) courses were all important

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factors related to students' choosing a post-secondary STEM path. When students took more STEM AP courses, their success in STEM disciplines increased which led them to the persistence in STEM (Grififth, 2010). High school Calculus was one of the variables mostly commonly found in the studies that predicted students' STEM degree attainment (Tai, Sadler et al., 2006; Tyson et al., 2007). Calculus has been shown to account for more than third of the variance in STEM attainment (Tai, Sadler et al., 2006; Tyson et al., 2007). Secondary to Calculus, other STEM related high school courses such as Precalculus, Trigonometry, Statistics, Chemistry, and Physics have also been linked to STEM attainment (Tyson et al., 2007). Thus, students' high school success is inextricable from post-secondary STEM success; however, that factor is not the only one.

Students' achievement in early grades was an essential component for pursuing STEM degree. Even though mostly high school courses and/or tests taken in the high school were influential, students' achievements in middle school were also important on predicting their STEM major decisions. Students need preparation in science and mathematics at early ages to pursue STEM careers (Brody, 2006). Effective education increases students' mathematics and science achievement (Successful STEM education, 2014). Students aspired to a greater degree to STEM fields as they achieved in science and mathematics (Tai, Liu, Maltase, & Fan, 2006). When students in middle school are not well prepared for science and mathematics courses, they continue to lag their peers in high school in advanced courses (Nicholls et al., 2010). If students are identified earlier and supported appropriately they could be as successful as their peers who

enrolled in STEM majors (Nicholls et al., 2010). There is large difference for high and

average mathematics achievers in 8th grade. For example, the expectancy for high 8th

grade mathematics achiever to earn a STEM degree is greater and 50% but 34% for

average achievers (Tai, Liu et al., 2006). As one would expect, when students have high

expectancy and high achievement they are more likely to earn STEM degrees as opposed

to students with both low expectancy and achievement (Tai, Liu et al., 2006). Finally, if

students are successful in mathematics and science in middle school they will be more

likely to pursue high school courses aligned with post-secondary STEM.

Advancing STEM with Early Opportunities

To maximize students' options to pursue STEM education, they should be

introduced to effective science and mathematics teaching and learning at an early age.

Because STEM education through research-based instruction links S-T-E-M disciplines

it is influential on students' science and mathematics learning (Corlu, Capraro, &

Capraro, 2014). Thus, when integrated STEM education is given in the formal learning

environment, it is expected to yield the following desired outcomes: (a) improvement of

students' science and mathematics achievement (Judson, 2013; Wiswall et al., 2014;

Young et al., 2011), (b) increase of students' interest in and attitudes toward STEM

(Parker, 2010; Means et al., 2014), and (c) encouragement of student to pursue post-

secondary STEM (Almarode et al., 2014; Coward, Zaier, & Hamman, 2010). While all

these outcomes are considered important, not all studies have been inclusive of all three

outcomes. To examine whether the desired outcomes were achieved, researchers

investigated the effectiveness of various STEM interventions in middle schools for

students' academic achievement by considering the influence of early exposure to STEM.

Having early experience in STEM at the middle school level could lead to positive outcomes in STEM disciplines. To have positive outcomes at early grades, STEM education should be introduced to students through research-based instruction strategies such as inquiry learning and project-based learning (PBL). These strategies are effective for enhancing teaching and learning (Capraro, Capraro, & Morgan, 2013) in STEM. It was found that when middle school students had an experience with PBL, their reading, mathematics (Olivarez, 2013), and science (Kutch, 2011; Olivarez, 2013) scores were improved and their affinity for high school science and mathematics classes was increased (Saad, 2014). In addition, science and mathematics classes integrated with engineering in middle school strengthened students' learning, improved their usage of engineering design process, and increased their interest in school and STEM (Goodwin, Brawley, Ferguason, Price, & Whitehair, 2013). Moreover, these types of classes offered in eighth grade increased male, Asian, African American, and Hispanic students' achievement in science and mathematics (Cantrell, Pekcan, Itani, & Velasquez-Brytant, 2006). The importance of STEM education at early ages is born of the idea that more STEM experience brings more success (Lambert, 2014). This has been shown through the comparision of percentage above grade level at various stages. For example, less than half a 6th and 7th graders performed above grade level however, by 8th grade STEM experience was paying "educational dividends" with 60% performing above grade level

(Lambert, 2014). Therefore, the implementation of STEM education should start as early as possible to ensure STEM capable and interested students are successful.

STEM Schools in the U.S.

The creation of STEM schools in the United States (U.S.) started with the urgency of having insufficient number of individuals who will pursue STEM degrees and careers. While the specialized STEM schools for gifted and talented students has been in existence, policymakers noted that the number of STEM graduates or people who pursue STEM career was not adequate (Agustine et al., 2005; PCAST, 2010). Therefore, PCAST (2010) suggested creating 1000 STEM-focused schools –200 new STEM high schools – in addition to other recommendations such as preparing 100,000 new STEM teachers, including more technology in education, and enhancing extracurricular activities. Since the beginning of 21st century, the number of STEM schools has increased constantly to encourage students to pursue STEM degrees and careers.

STEM schools were classified under four types. The four types of STEM schools in the U.S. are selective, inclusive, career and technical, and comprehensive (NRC, 2011). Selective STEM schools have admission criteria and mostly educate gifted and talented students (Means, Confrey, House, & Bhanot, 2008; NRC, 2011a, 2013). Inclusive STEM schools do not have selection criteria and are open-admission schools (Means et al., 2008; NRC, 2011a, 2013; Young et al., 2011). STEM-focused career and technical schools prepare students to enter the STEM workforce without requiring a college degree (NRC, 2011a, 2013; Stone III, 2011). STEM-focused comprehensive

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schools are designed to provide comprehensive knowledge and skills to students in

STEM disciplines in addition to other subject areas (NRC, 2011a, 2013).

T-STEM Academies

Among four types of STEM schools, the inclusive STEM high schools were the

most common type in the U.S. (Rogers-Chapman, 2013). Texas is one of states that has a

considerable number of inclusive STEM schools (Young et al., 2011). STEM schools in

the state of Texas are named T-STEM academies. They opened in 2006 and as of 2012-

13, the number of T-STEM academies reached 65. The goals of T-STEM academies

were to increase students' science and mathematics achievement in Texas (Avery et al.,

2010), enhance the number of students who are interested in and enroll in STEM degrees

and careers, improve teachers' knowledge and skills through high-quality professional

developments, and promote school leadership (Educate Texas, 2013b). Given the

specific set of goals, STEM schools in Texas represents a noteworthy model for study.

Educate Texas and Texas Education Agency developed a standardized document

to help schools meet the goals. To achieve the goals, T-STEM academies were expected

to implement the T-STEM Academy Blueprint Design (ABD). In the T-STEM ABD,

there were seven benchmarks (THSP, 2010): (1) mission-driven leadership, (2) T-STEM

culture, (3) student outreach, recruitment, and retention, (4) teacher selection,

development and retention, (5) curriculum, instruction, and assessment, (6) strategic

alliances, and (7) academy advancement and sustainability. These benchmarks were

designed to ensure the STEM school culture and have a well-defined guide for

stakeholders during planning and implementation (Avery et al., 2010; Texas

Administrative Code [TAC], 2011; THSP, 2010; Young et al., 2011). The first report (Young et al., 2011) contained information about the effectiveness of T-STEM academies. This report revealed the fact that the quality of the implementation plays an important role on the success of the school. The first three years of these schools were examined, it was pointed out that the more experienced the T-STEM academy, the greater the effectiveness of the program (Young et al., 2011). T-STEM ABD included implementation benchmarks by which schools could judge their progress on a rubric (Avery et al., 2010). The T-STEM ABD rubric included four phases: developing, implementing, mature, and role model. According to the rubric, at the end of the fourth year, the academy was expected to be a role model and have enough experience to have a well-developed STEM culture. As a result, one would expect that the success of students in T-STEM academies at the end of their fourth year would be greater because of established curriculum, instruction, and experienced teachers.

The purpose of the study is to disentangle the effects of early exposure to the Texas STEM model on student achievement. Therefore, there are two purposes for this study. The first is to examine the effects on high school student achievement in mathematics and science for students who were educated in a middle school implementing the Texas model. To address the first purpose the students who experienced the extended STEM model was compared to a group students who had not but were attending a T-STEM high school where the schools had at least three years of being a T-STEM academy. The two groups of students were compared based on science (i.e., biology, chemistry, and physics) and mathematics (i.e., Algebra I, Algebra II, and

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geometry) scores. The students who had the middle school experience were in a 6-12 T-STEM school. The second purpose of the study was to examine the effects the number of years a school was a T-STEM academy on student achievement. Because the Blue Print sets the expectation that schools be at the level of role model in the 4th year of implementation the cutoff for comparison was less than 4 and equal to 4 years or greater than 4 years.

Methodology

In order address the research questions, this study was divided into two parts. The focus for the first part of the study was to disentangle the effects of matriculating into a T-STEM academy in middle school as compared to matriculating for high school. To compare achievement, students' STAAR test scores were used. A One-way analysis of variance (ANOVA) was used to examine students' mean STAAR end of course exam scores between two groups: (1) attended T-STEM academy for middle grades and (2) attended T-STEM academy for high school only. The second part focused on investigating the differences between two groups based on years of designation as a T-STEM academy: (1) with four or more years and (2) less than four years of successful operation. T-STEM academies success was assessed by students' TAKS score results; therefore students' TAKS scores were used. Hierarchical linear modeling was used to examine students' achievement difference between those groups of T-STEM academies. The reminder of the report was divided into two sections: the part one for research question one and part two for research question two.

Participants

  Part 1 (6-12 vs 9-12 T-STEM academies). The number of participants varied by subject area exam. Generally in Texas, 9th and 10th graders took Algebra I, Algebra II, geometry, chemistry, and biology end of course exams. The number of participants for this part of the study was reported according to academic subject and its available grade in the data set for T-STEM academies.

  The participants varied by grade and subject. For the entire sample, there were 483 9th grade Algebra I, 361 10th grade Algebra II, 747 9th and 10th grade geometry, 865 10th grade chemistry, and 1220 9th grade biology scores. Eighth grade Algebra I scores were omitted from the analysis because they were not available for the 9-12 T-STEM academy configuration. The demographic information of the entire sample and the number of students in the two groups of T-STEM academies (i.e., 6-12 and 9-12) was represented in Table 22 by academic subject area.

Table 22

Demographics for Each Subject

Variable	Algebra I 9th	Algebra II 10th	Geometry		Chemistry 10th	Biology 9th
			9th	10th		
Female	271	219	240	163	485	639
	(56.1%)	(60.7%)	(52.1%)	(57%)	(56.1%)	(52.4%)
Male	212	142	221	123	380	581
	(43.9%)	(39.3%)	(47.9%)	(43%)	(43.9%)	(47.6%)
Asian	27	24	78	19	56	102
	(5.6%)	(6.6%)	(16.9%)	(6.6%)	(6.5%)	(8.4%)
AA*	48	5	0	34	84	80
	(9.9%)	(1.4%)	(0%)	(11.9%)	(9.7%)	(6.6%)
Hispanic	395	307	352	218	675	936
	(81.8%)	(85%)	(76.4%)	(76.2%)	(78%)	(76.7%)
White	13	25	31	15	50	102
	(2.7%)	(6.9%)	(6.7%)	(5.2%)	(5.8%)	(8.4%)
6-12	387	331	384	210	729	1010
	(80.1%)	(91.7%)	(83.3%)	(73.4%)	(84.3%)	(82.8%)
9-12	96	30	77	76	136	210
	(19.9%)	(8.3%)	(16.7%)	(26.6%)	(15.7%)	(17.2%)

*AA: African American

There were two types of T-STEM academies in the state: (a) school-within-a school and (b) stand-alone. The participants in this study were from stand-alone T-STEM academies. Only stand-alone academies students' scores could reveal unbiased results because school-within-a school academies' results included STEM and non-STEM students. Non-STEM students refer to the group of students who did not receive STEM practices in the school whereas STEM students had the benefit of T-STEM ADB and experienced a STEM curriculum. In the dataset, if a school was school-within-a-school model, two groups of students' scores were listed. The data reported to the TEA did not include STEM participation for students in a school-within-a-school. As a result, only stand-alone T-STEM academies were included in the analyses.

In 2012-2013, there were 37 stand-alone T-STEM academies in the state. To reduce the effect of academies' experience on students' achievement, T-STEM academies that served at least four years were selected for ninth grade students' data. Thus, T-STEM academies that served during 2006-07, 2007-08, 2008-09, and 2009-10 academic years were included in the analysis for 9th grade Algebra I, geometry, and biology courses. Therefore, 12 T-STEM academies were lost because they had not been designated during these four years and the remaining 25 stand-alone T-STEM academies were included. For tenth grade students' data, T-STEM academies that served at least five years were selected. The number of T-STEM academies, which served during 2006-07, 2007-08, and 2008-09, was 23 for 10th grade Algebra II, geometry, and chemistry courses.

Not all T-STEM academies offered the same courses. Because course choice is the function of the number of students in the school and the number of students prepared to be successful in that course. Therefore, T-STEM academies offer courses based on population specific criteria.

There is a limitation for this part of this part of the study. When examining the 6-12 configuration, it was impossible to know, with certainty, that every 9th grade student actually attended a 6-12 configuration for his or her preceding two years. Some possibilities include: having been home-schooled and then placed in the 6-12 configuration in 9th grade, or having transferred from any other school 6-12 T-STEM academy or not.

Part 2 (T-STEM academy duration). In this part of the study, there were 2454 eleventh grade students in T-STEM academies in the 2012-2013 academic year. Some of these students took the alternative version of TAKS test. For instance, TAKS-M is the modified version of TAKS test for special education students. Alternate versions of TAKS tests were removed from the sample. As a result, there were 2415, 2425, and 2418 students that took mathematics, reading, and science TAKS tests, respectively in spring 2013. The demographic distribution of participants for each academic subject was displayed in Table 24. Only 26 students were represented as being American Indian or Alaskan Native (N=8), Native Hawaiian or other Pacific Islander (N=2), or as Two or more Races (N=16).

Table 23

Percentages of Participants in Each Subject by Demographics

Variable	Category	Mathematics	Reading	Science
Gender	Female	49.5%	49.4%	49.4%
	Male	50.5%	50.6%	50.6%
	Asian	4.8%	4.8%	4.8%
Ethnicity	African American	21.3%	21.4%	21.3%
	Hispanic	58.8%	58.6%	58.8%
	White	14.1%	14.1%	14.1%

In this part of the study, similar to part 1, for the same reason, only stand-alone T-STEM academies were analyzed. There were 37 stand-alone T-STEM academies in 2012-2013. However two T-STEM academies changed to middle school and stopped serving high school and were lost to the study leaving 35 stand-alone T-STEM academies. In the data set, there were 35 available to analyze for 11th graders because two schools changed their grade span to middle grades. T-STEM academies were divided into two groups: a) group 1: T-STEM academies with less than 4 years of experience (N=10), and b) group 2: T-STEM academies with at least four years of experience (N=25). This grouping was also used as school level variable (i.e., dichotomous variable).

Estimation of student learning

Part 1. To determine students' academic achievement, students' high-stake test scores were used. In the state of Texas, the STAAR test was administered as the high-stakes test after 2012 (TEA & Pearson, 2013). This test was an end of course exam for high school courses. Therefore, in 2013, the STAAR test was administered for Algebra I, Algebra II, geometry, biology, chemistry, physics, U.S. history, world geography, world history, English I reading-writing, English II reading-writing, and English III Reading-writing. In 2014, the testing load was reduced to only Algebra I, biology, U.S. history, English I reading-writing, and English II reading-writing. In part 1 of this study, only students' mathematics and science scores were the interest; therefore, students in 2012-13 spring term, Algebra I, Algebra II, geometry, biology, and chemistry scores were analyzed. Due to low enrollment, T-STEM academy students' physics scores were not analyzed.

The reliability coefficients of each end of course exam were reported. The reliability coefficients for the STAAR test for each academic subject were: a) 0.91 for Algebra I, b) 0.88 for Algebra II, c) 0.89 for geometry, d) 0.90 for biology, e) 0.89 for chemistry, and e) 0.91 for physics (TEA & Pearson, 2014).

Part 2. To analyze the second research question in this study, students' TAKS scores were used. The TAKS test was high-stakes test until 2012. In 2012, STAAR test was administered as well as TAKS depending on students' grade level. After the first administration of STAAR in 2012, each year the subsequent grade level was added. For instance, in 2011, all students in ninth through eleventh grade were tested with TAKS. In

2012, ninth graders were tested with STAAR, 10th-11th graders were tested with TAKS. In 2013, 9th and 10th grade students took STARR, and 11th grade students took the TAKS. For part 2 of the study, the goal was to examine the effect of the length of time a T-STEM academy was in operation. According to TEA, the T-STEM ADB can take long as four year to reach role-model status.

The reliability coefficients for the TAKS test for each academic subject were released each year. Reliability coefficients for mathematics, reading, and science were 0.90, 0.85, and 0.85 in 2013, respectively (TEA & Pearson, 2013).

Data Analysis

Part 1 (6-12 vs 9-12 T-STEM academies). To analyze students' mean score difference between two groups ANOVA was used. ANOVA is a statistical analysis to examine whether sample means differ from each other (Cohen & Lea, 2004). One-way ANOVA is used to evaluate mean differences between two or more than two groups, when a single and at least intervally-scaled variable was used as dependent variable (Thompson, 2006). For the first research question, the purpose was to determine the difference, if there is, between students in two groups of T-STEM academies.

In this part of the study, there were five hypotheses. There were five outcomes: (1) 9th grade Algebra I scores, (2) 10th grade Algebra II scores, (3) 9th and 10th grade geometry scores, (4) 10th grade chemistry scores, and (5) 9th grade biology scores. When there are more than one hypothesis in a study, the probability of having made more than one Type I error rate (i.e., experimentwise error rate) will be higher than p value (i.e., testwise error rate) unless hypotheses are perfectly correlated (Thompson, 2006).

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Because there was more than one hypothesis in this study, one method to control experimentwise error rate was use, which was Bonferroni correction. This correction is the division of p value by the number of hypotheses. In this study, p value was chosen as 0.05 and the corrected testwise error rate would be 0.025 (i.e., 0.05/2=0.008). The reason for diving by two was because the same 9th graders and 10th graders were represented in two groups for which p values were estimated.

Part 2 (T-STEM academy duration). Units in educational contexts usually have nested structure. For instance, students nested within classrooms, classroom nested within schools, and schools nested within districts. The nested structure is a common phenomenon in educational studies (Osborne, 2000) and because of hierarchical structure of data, the violation of the independence of observations assumption is one problem. HLM was a useful analysis method to avoid the violation of the independence of observations assumption (Hox, 2002).

In this study, the data were nested. Students were nested within condition. To analyze the effect of T-STEM academies' experience throughout the years, a new school level variable (i.e., group) was created, and students' mathematics, reading, and science scores were used as outcome variables. As a result, because of the nested structure of the data, a two-level HLM was used to answer the second research question.

Missing data is one of the problems that a researcher could encounter. It is common to have missing data in quantitative studies (Baraldi & Enders, 2010). It is important to know what type of missing data mechanisms the study has. Missing completely at random (MCAR) is one type. In MCAR, the probability of missing data is

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unrelated to other measured variables (Little & Rubin, 2002). Thirty-six percent of the data were missing. The correlation of missing data to all other variables was less than 0.30. The reason of why these students' scores were missing was unknown. For instance, students could have moved to another school or did not take that test during spring term. In this case, a missing data technique can prevent the loss of other important data. Multiple imputation (MI) is one technique that produces unbiased estimates in MCAR (Baraldi & Enders, 2010). Therefore, MI was used to estimate missing values before the HLM analysis.

The first model, fully unconditional, with students nested within schools was analyzed to determine whether the data was appropriate for higher levels (Raudenbush & Bryk, 2002). The reading, mathematics, and science scores were labeled ACHIEVEMENT in every model to keep the models generic. The first model equations by levels were:

Level 1 Equation: $ACHIEVEMENT_{ij} = \beta_{0j} + r_{ij}$

Level 2 Equation: $\beta_{0j} = \gamma_{00} + u_{0j}$

The intraclass correlation (ICC) was computed after the first model to determine the proportion of variance explained by grouping structure (Hox, 1995). The formula $\rho = \tau_\beta / \sigma^2 + \tau_\beta$ was used to represent proportion of variance between schools, where τ_β is level-2 variance, and σ^2 is residual variance (Raudenbush & Bryk, 2002). In educational context, ICC of 0.10 and 0.15 was defined as reasonable and high, respectively (Hox, 2002). The suggested rule of thumb for ICC was 0.05, 0.10, and 0.15 as small, medium, and large values, respectively (Hox, 2002).

The second, final, model included school level variable (i.e., group) that indicates

the experience of T-STEM academies in terms of years. The second model by levels

were:

Level 1 Equation: $ACHIEVEMENT_{ij} = \beta_{0j} + r_{ij}$
Level 2 Equation: $\beta_{0j} = \gamma_{00} + \gamma_{01} * (Group) + u_{0j}$

In this study, maximum likelihood estimation with robust standard errors was

used. This estimation can be used under MCAR for continious variables (Little & Rubin,

2002; Muthén & Muthén, 2012). This method was also the default in M*plus* 7 for

multiple imputation.

Results

Key Features of the Data

Part 1 (6-12 vs 9-12 T-STEM academies). Students' mean scores and standard

deviations in five subjects were provided as descriptive statistics of this study. Students,

who were in T-STEM academies since 6th grades, had higher mean scores than other

students, who were in T-STEM academies since 9th grades, in Algebra I, Algebra II, and

chemistry (see Table 24). For geometry, students' mean scores in T-STEM academies

serving 9-12th grade had higher mean score than their counterparts. In addition, for

biology, students who had been in T-STEM academies for one years had higher mean

scores than others who had been in T-STEM academies for 4 years.

Table 24

Students' Mean Scores and Standard Deviations by Academic Subjects for Each group

	6-12		9-12	
Subjects	Mean	*SD*	Mean	*SD*
Algebra I (9th)	3920.65	393.57	3777.98	469.98
Algebra II (10th)	4281.46	530.41	4038.83	374.34
Geometry (9th&10th)	4094.81	476.37	4157.32	487.907
Chemistry (10th)	4094.71	486.57	4023.33	440.66
Biology (9th)	4069.03	449.69	4115.04	456.86

Part 2 (T-STEM academy duration). Descriptive statistics gives critical information about the data. In this part of the study, students' mean scores were represented by their gender and ethnicity for three traditional academic subjects by T-STEM academy group (see Table 25). For students in T-STEM academies serving less than four years, male students' mean mathematics and science scores were higher than females, whereas females' reading mean score was higher than males. The ranking from highest to lowest for mathematics scores by ethnicity was Asian, White, Hispanic, and African American (e.g. Capraro, Young et al., 2009). The ranking from highest to lowest for reading scores by ethnicity was White, Asian, Hispanic, and African American. In science, Asian students scored higher than White, White higher than African American, and African American higher than Hispanic students.

For students, who were in T-STEM academies serving at least four years showed somewhat similar trend as T-STEM academies serving less than four years in terms of students' demographics. Male students had higher mathematics and science scores than females. The ranking from highest to lowest for mathematics and science scores by ethnicity was Asian, White, Hispanic, and African American. For reading, the ranking from highest to lowest was White, Hispanic, Asian, and African American. In general, students in T-STEM academies serving at least for four years had higher scores than students in T-STEM academies serving less than four years, which showed that more experience had positive effect on students' mathematics, reading, and science achievement.

Table 25

T-STEM Academies Students' Mean Scores by Academic Subject and Experience

| Demographics | Mathematics | | Reading | | Science | |
| | <4 years | ≥4 years | <4 years | ≥4 years | <4 years | ≥4 years |
	Mean	Mean	Mean	Mean	Mean	Mean
Female	2202.64	2329.86	2245.09	2345.17	2205.04	2271.36
Male	2209.71	2383.01	2226.43	2315.00	2231.74	2349.98
Asian	2434.14	2458.05	2248.66	2326.82	2391.13	2377.71
AA*	2190.49	2128.14	2227.26	2134.86	2221.15	2055.38
Hispanic	2208.83	2346.80	2231.58	2336.86	2208.79	2314.44
White	2314.77	2354.00	2329.32	2295.62	2322.37	2344.24

*AA: African American

Inferential Statistics Results

    Part 1. ANOVA results. To examine the effectiveness of early exposure to STEM practices, students mathematics and science end of course exam mean scores were analyzed. To analyze the mean score difference between two groups of T-STEM academies one way ANOVA was used. One of the important assumption in ANOVA is homogeneity of variance. This assumption is required because when sum of squares are pooled, it would not logical to average them when they are not similar (Thompson, 2006). Therefore, homogeneity of variance assumption needs to be met to interpret

statistical significance testing and effect size. In this study, for six hypotheses, the homogeneity of variance assumption tested and met.

The ANOVA results showed that there was a statistical significant (p=0.002) difference between two groups of T-STEM academies at the 0.025 alpha level in Algebra I. According to the mean scores of two groups, the group attended T-STEM academies earlier than high school had higher scores than other group.

Table 26

ANOVA Results for Algebra I

Source	SOS	df	MS	$F_{calculated}$	$p_{calculated}$	η^2	ω^2
Between	1565714.38	1	1565714.38	9.323	.002	0.019	0.016
Within	80775465.86	481	167932.36				
Total	82341180.25	482					

The ANOVA results for Algebra II indicated that there was a statistically significant (p=0.015) difference between two groups of students at the 0.025 alpha level. For Algebra II, the group who attended T-STEM academy in middle school had higher mean score than who started T-STEM in high school.

Table 27 ANOVA

Results for Algebra II

Source	SOS	df	MS	$F_{calculated}$	$p_{calculated}$	η^2	ω^2
Between	1619218.59	1	1619218.59	5.999	.015	0.016	0.013
Within	96903934.28	359	269927.39				
Total	98523152.87	360					

The ANOVA results for geometry indicated that there was not a statistically significant (p=0.15) difference between two groups of students (see Table 28).

Table 28

ANOVA Results for Geometry

Source	SOS	df	MS	$F_{calculated}$	$p_{calculated}$	η^2	ω^2
Between	475168.19	1	475168.19	2.073	.150	0.002	0.001
Within	170530444.90	744	229207.58				
Total	171005613.09	745					

In terms of students science scores, chemistry and biology, there was not a statistically significant difference between the two groups of students (see Table 29 and 30).

Table 29

ANOVA Results for Chemistry

Source	*SOS*	*df*	*MS*	$F_{\text{calculated}}$	$p_{\text{calculated}}$	η^2	ω^2
Between	583937.19	1	583937.19	2.538	.112	0.002	0.001
Within	198571376.87	863	230094.29				
Total	199155314.06	864					

Table 30

ANOVA Results for Biology

Source	*SOS*	*df*	*MS*	$F_{\text{calculated}}$	$p_{\text{calculated}}$	η^2	ω^2
Between	368021.88	1	368021.88	1.810	.179	0.001	<0.001
Within	247662899.86	1218	203335.71				
Total	248030921.74	1219					

Part 2. HLM analyses. The data were analyzed using M*plus* 7 software. Two-level HLM was used to investigate students' mathematics, reading, and science achievement for two types of T-STEM academies. The unconditinal model explored how much of the variation in outcome variable was within and between schools.

Unconditional model. The grand mean (γ_{000}), the estimated within-school variance (σ^2), and between-school variance (τ_β) were shown in Table 31 for each academic subject. According to the unconditional model, there was 12% variation

between schools for mathematics, reading, science. This indicated that there was sufficient variation in the second level to examine.

Table 31

Grand Mean, Within and Between School Variance for Mathematics, Reading, and Science Scores

	Grand mean	Within-school variance (σ^2)	Between-school variance (τ_β)
Mathematics	2312.36	33984.74	4953.52
Reading	2307.89	28187.49	3926.51
Science	2304.27	22419.15	3081.48

Final model. In the final model, the school level variable was added to the baseline model to examine the how much of the variation of school level was explained by grouping variable. The variable group accounted for 49% of the parameter variance in mathematics, 35 % for reading and 5% for science. For mathematics and reading, the variable group, whether the T-STEM academy had more than four years of experience, accounted for a noteworthy percentage of the variation. For science, the group to which a student belonged, did not have a notable impact on the accounted for variance. Table 32 displays the unconditional and final model school level variances. When T-STEM academies had at least four years of experience, on average, their students' mean scores

increased 70.54 (M) (p=0.01), 70.54 (R) (p=0.01), and 57.05 (S) (p=0.02) points. This showed that if a T-STEM academy had at least four years or more experience of application of STEM practices, this increases students' mathematics, reading, and science achievement significantly.

Table 32

Variance Components of School Level for Unconditional and Final Model

	Unconditional Model	Final Model
Mathematics	4953.52	2526.71
Reading	3926.51	2526.73
Science	3081.48	2904.08

Conclusion

The current study highlights the importance of beginning STEM education in the middle grades year and the value of matriculating into a STEM school with at least 4 years of experience. The results indicate that teaching STEM practices in middle grades increases students' mathematics and science achievement for later years. In addition, when STEM schools have more experience, they get closer to achieving TEA benchmarks, which are aligned with the improvement of students' academic achievement on high-stakes tests.

For part one, there was meaningful improvement albeit limited. The greatest benefit for students who participate in a middle school STEM academy is in the areas of Algebra I and II. The important caveat is that there was no difference for science and geometry. While these findings indicate a reason to be supportive of middle grades STEM academies, there is sufficient pause for concern. It is unclear why higher algebra achievement in a 6-12 program would not lead to sustained math achievement that would carry over into geometry. Perhaps, the STEM mission and content are not well aligned with geometry content and teacher learning expectations. Algebra is one of the mathematic areas specifically introduced to students starting in middle grade and has increasing content trend over years whereas geometry is not emphasized as much as algebra in Texas Essential Knowledge and Skills for Mathematics in middle grades.

One of the T-STEM academies' primary purposes is to increase students' mathematics and science achievement to facilitate post secondary matriculation. To increase academic performance, it is important to use learning strategies that foster understanding rather than rote-memorization. STEM practices such as project-based learning are helpful teaching-learning strategies for meaningful learning (e.g., Capraro, Capraro, & Morgan, 2013; Capraro, Capraro, Morgan, Scheurich et al., 2015). These practices should be applied in a well-designed environment. This requires teacher preparation and experience. One reason that students' science scores in T-STEM academies were not as successful as expected might be the lack of well-trained and qualified teachers (see Oner, 2015, chapter III). This also shows the importance teacher experience as well as the schools' experience with implementing STEM practices.

The second part of the study highlights the importance of the duration of implementation of STEM practices. In Texas, STEM schools have a specific design model, T-STEM ADB. T-STEM ADB assists T-STEM academies to be a successful academy with its proposed benchmarks. T-STEM academies should implement these benchmarks to be a successful school. Each year while their experience increases, they also assume the mantle of becoming a role-model implementation at the end of their fourth year. As T-STEM academy gains experience from year to year, building on successes while minimizing failures increases student performance and learning. The study clearly differentiates between academies with sufficient experience from those still growing in the implementation model. There are no set specific years by which one can determine if a school has met all requirements to be considered a role model school. However there is clear time period by which a school must meet the benchmark. Therefore, it is possible that some of the schools with less then four year of experience could be at the cusp of role model implementation.

CHAPTER VI

SUMMARY AND CONCLUSION

There has been an increasing emphasis on enhancing the number of students pursing STEM degrees and STEM graduates. To reach desired results, the establishment of STEM schools in the U.S. was taken as one action (PCAST, 2010). While the number of STEM schools in the U.S. has been increasing, it was important to examine the change to determine whether these schools were effective with regard to increasing students' achievement. The focus of the present dissertation study was on STEM schools in the state of Texas to determine the influence of STEM schools on students' performance. The results contained in this dissertation provide an initial step in achieving the desired outcome, more STEM graduates.

To highlight the key the findings from the chapters from this dissertation, Figure X provides an overview. In this figure, there were four components in relationship with T-STEM academies. The T-STEM academies are the focal point of this dissertation and it represents the goal that is successful STEM implementation. Other components were middle school implementation, duration of STEM schools' experience, educational service centers, and the outcome for specific group of students.
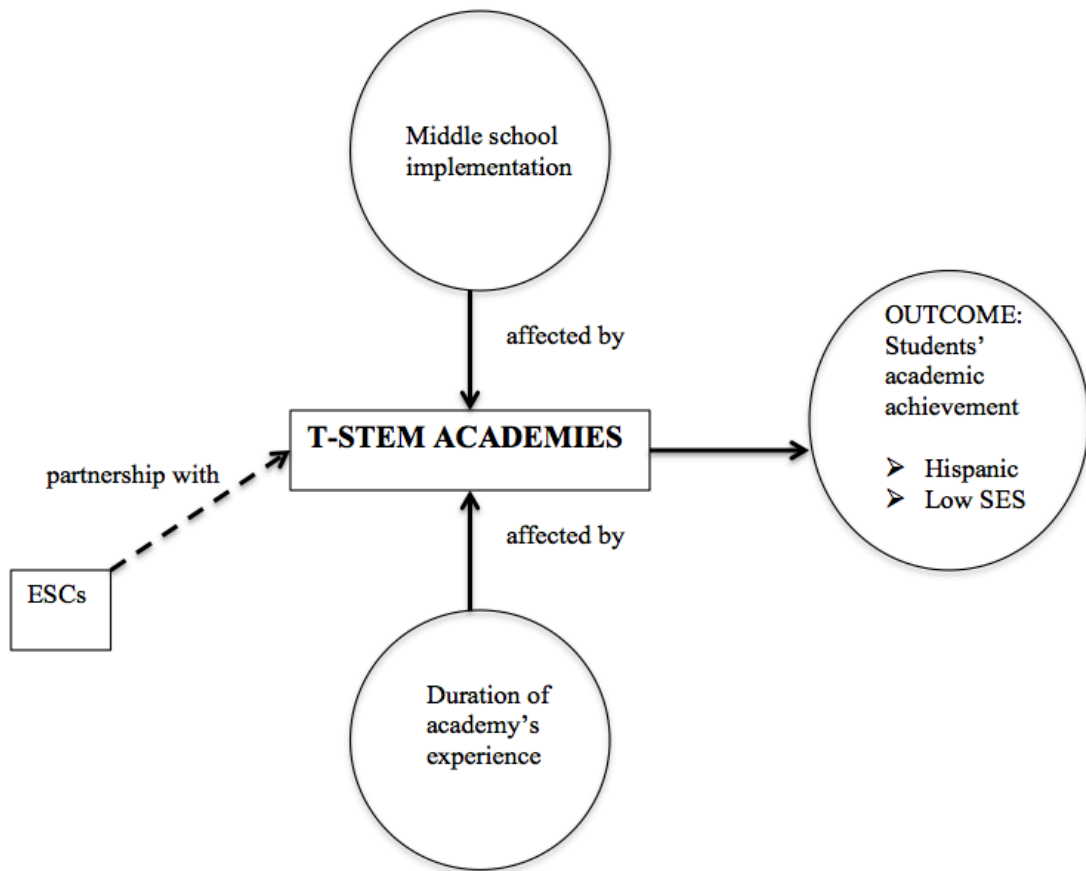
Figure 9. Influential factors influencing T-STEM student success

       The component ESCs shows the partnership with T-STEM academies. The main

goal of ESCs is to provide service for instructions and instructional materials (Floyd,

2007). T-STEM academies are expected to use well-designed STEM practices. During

the implementation of these practices, T-STEM academies could need assistance about

instructional approaches. For instance, these academies should be partner with STEM

centers, coaches to enhance the instruction. In this case, ESCs are one of the institutions

that should provide assistance for these academies. The results highlight the assistance provided by ESCs is of unknown value whether it is sufficient or not. It is possible that all ESCs are performing on par either doing a great deal for T-STEM academies or nothing. What could be troubling is that two ESCs are also T-STEM Centers. While these two ESCs did not excel in the comparison, it would seem that ESCs are not well situated to provide the level of service required.

One of the components that influences T-STEM academies' student achievement is middle school implementation. The importance and effect of beginning STEM practices in the middle school had noteworthy benefits. The findings showed that being taught with STEM practices has a positive effect on students' mathematics achievement. Students' science achievement, however, did not change according to their middle school type. Implementation plays a very important role. Thus, one reason might be the lack of well-designed implementation in science or teachers' insufficient experience to use new teaching strategies for STEM practices. Mathematics requires prerequisite content knowledge to build new learning; however, science requires mathematics knowledge as well as prerequisite science understanding. This requires science teachers to be qualified in both content areas in order for them to provide beneficial teaching. As a result, to determine the reason why attending T-STEM academy in middle grade does not have an influence on science, a qualitative study might shed important light on the topic.

T-STEM academy experience is another component that influences students achievement. T-STEM academies are expected to be a role model by the end of their

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fourth year according to T-STEM ADB. It was concluded that if a T-STEM academy has experience implementing the T-STEM ADB for at least four years, their students' academic achievement is better than less experienced ones. This result supports the importance of implementation and the quality of the implementation. It is inevitable that teachers in these academies gain experience each year, and this would influence their students' success if their implementation changes positively every year. There might be an academy whose designation is less than four years; however, its teachers are well-trained and successful to implement STEM practices. In that case, the cut off value (i.e., four years) to be a role model would not be valid for that school and actually, that school could serve as a role model for other academies earlier. However, to determine whether there are such academies in Texas, more investigation is needed.

With the effect of the initial implementation year and experience as a T-STEM academy are key variables aligned to improve particular groups of students' academic achievement. Specifically, T-STEM academy instruction is beneficial to Hispanic students. These students showed higher success than other Hispanic students in non-T-STEM schools: (a) traditional high schools, and (b) charter schools. Economically disadvantaged (i.e., low SES) students are another group whose academic performance increased over time in T-STEM academies compared to non T-STEM schools. These results are promising because in general the majority of the participants were Hispanic and low SES. These findings also indicate that T-STEM academies partially fulfill their promise.

However, African American students seem to remain underserved across both T-STEM academies and Non T_STEM schools. While African American students showed persistent decline in performance overtime that decline was seen across both –STEM school s and non T-STEM schools. These findings indicate that teaching strategies and perhaps cultural bias could be responsible for the decline in performance. Perhaps African American students do not experience the STEM curriculum and T-STEM ADB in ways that fit their own cultural expectations. One consideration would be to infuse culturally relevant pedagogies in the teaching and learning process for T-STEM academies.

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Model 1: Unconditional Model

Level-1 Model

$$\text{MATH}_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + e_{ijk}$$

Level-2 Model

$$\pi_{0jk} = \beta_{00k} + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k} + r_{1jk}$$

Level-3 Model

$$\beta_{00k} = \gamma_{000} + u_{00k}$$

$$\beta_{10k} = \gamma_{100} + u_{10k}$$

Mixed Model

$$MATH_{ijk} = \gamma_{000} + \gamma_{100}*TIME_{ijk} + r_{0jk} + r_{1jk}*TIME_{ijk} + u_{00k} + u_{10k}*TIME_{ijk} + e_{ijk}$$

Model 2

Level-1 Model

$\text{MATH}_{ijk} = \pi_{0jk} + \pi_{1jk}*(TIME_{ijk}) + e_{ijk}$

Level-2 Model

$\pi_{0jk} = \beta_{00k} + \beta_{01k}*(H_{jk}) + \beta_{02k}*(AA_{jk}) + \beta_{03k}*(AS_{jk}) + \beta_{04k}*(DIS_{jk})$

$+ \beta_{05k}*(FEMALE_{jk}) + r_{0jk}$

$\pi_{1jk} = \beta_{10k} + \beta_{11k}*(H_{jk}) + \beta_{12k}*(AA_{jk}) + \beta_{13k}*(AS_{jk}) + \beta_{14k}*(DIS_{jk})$

$+ \beta_{15k}*(FEMALE_{jk}) + r_{1jk}$

Level-3 Model

$\beta_{00k} = \gamma_{000} + u_{00k}$

$\beta_{01k} = \gamma_{010} + u_{01k}$

$\beta_{02k} = \gamma_{020} + u_{02k}$

$\beta_{03k} = \gamma_{030} + u_{03k}$

$\beta_{04k} = \gamma_{040} + u_{04k}$

$\beta_{05k} = \gamma_{050} + u_{05k}$

$\beta_{10k} = \gamma_{100} + u_{10k}$

$\beta_{11k} = \gamma_{110} + u_{11k}$

$\beta_{12k} = \gamma_{120} + u_{12k}$

$\beta_{13k} = \gamma_{130} + u_{13k}$

$\beta_{14k} = \gamma_{140} + u_{14k}$

$\beta_{15k} = \gamma_{150} + u_{15k}$

Mixed Model

$MATH_{ijk} = \gamma_{000} + \gamma_{010}*H_{jk} + \gamma_{020}*AA_{jk} + \gamma_{030}*AS_{jk}$

$+ \gamma_{040}*DIS_{jk} + \gamma_{050}*FEMALE_{jk} + \gamma_{100}*TIME_{ijk} + \gamma_{110}*TIME_{ijk}*H_{jk}$

$+ \gamma_{120}*TIME_{ijk}*AA_{jk} + \gamma_{130}*TIME_{ijk}*AS_{jk} + \gamma_{140}*TIME_{ijk}*DIS_{jk} +$

$\gamma_{150}*TIME_{ijk}*FEMALE_{jk} + r_{0jk} + r_{1jk}*TIME_{ijk} + u_{00k} + u_{01k}*H_{jk} + u_{02k}*AA_{jk} + u_{03k}$

$*AS_{jk} + u_{04k}*DIS_{jk} + u_{05k}*FEMALE_{jk} + u_{10k}*TIME_{ijk} + u_{11k}*TIME_{ijk}*H_{jk} + u_{12k}$

$*TIME_{ijk}*AA_{jk} + u_{13k}*TIME_{ijk}*AS_{jk} + u_{14k}*TIME_{ijk}*DIS_{jk} + u_{15k}$

$*TIME_{ijk}*FEMALE_{jk} + e_{ijk}$