STEM PROGRAMS IN TEXAS PUBLIC SCHOOLS

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Abstract

School staff are challenged to meet the needs of 21st century learners. Each public school campus is charged with preparing students for postsecondary success. An expectation of the Texas Education Agency (TEA) is that students meet a minimum standard on all tested subjects of the State of Texas of Academic Achievement Readiness assessment. Texas students historically do not perform as well as their international peers in the areas of math and science (Lee, Grigg, & Dion, 2007; Mullis, 2012). This quantitative comparison study was an investigation of STEM program effectiveness comparing T-STEM Academies with non-STEM campuses as they relate to student achievement in Texas public middle schools. State math and science assessment data will be the measure of performance of the five TEA T-STEM Academies and each of the forty TEA comparison campuses. T-STEM Academies often result in a greater campus percentage rate than respective comparison groups, however this is not true in all comparisons. Campus leaders and stakeholders will be able to evaluate the effectiveness of STEM program implementation, specifically T-STEM Academies.

Keywords: STEM Education, T-STEM, T-STEM Academy, Texas Education Agency (TEA), STAAR, 21st century learner

Educators are challenged to meet the needs of 21st century learners (Fleischman, Hopstock, Pelczar, & Shelley, 2010. According to the Texas Education Code, each public school campus is charged with preparing students for postsecondary success (Texas Education Agency, Chapter 28). The Texas Education Agency expects students to meet a minimum standard on each State of Texas of Academic Achievement Readiness assessment. United States students historically fall short of their international peers in the areas of math and science (Gonzales, Williams, Jocelyn, Roey, Kastberg, & Brenwald, 2008). Schools have many options for implementing Science Technology Engineering and Math (STEM) programs to support student achievement.

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According to the U.S. Department of Education's 2010 National Education Technology Plan, education is critical to the United States' success in an inner-connected, global economy and must be a priority. The effect of STEM program implementation on student achievement is worthy of study to evaluate program effectiveness. The problem is the low student performance in the areas of math and science in secondary schools (Glod, 2007). An inadequate number of high school graduates in the United States pursue careers in STEM fields (Fleischman et al., 2010). Educational stakeholders, district and campus administrators, and teacher preparation programs may benefit from considering the effect of STEM programs on student achievement.

STEM Terminology

For the purposes of this discussion, the term STEM refers to science, technology, engineering, and math. The National Science Foundation began using SMET in the 1900s as shorthand for science, math, engineering, and technology; however, there was complaint that it was too similar to "smut" resulting in the changed acronym (Sanders, 2008). Other related terms are relevant to the discussion of STEM content and practices. *Problem-based learning (PBL)* provides a learning environment "which focuses on spontaneity, collaboration, and flexible problem-solving skills, is such an approach that engages students in problem-solving scenarios" (Hung, Hwang, Lee, Wu, Vogel, Milrad, & Johansson, 2014, p. 316). *STEM Education* includes varied experiences integrated throughout content areas allowing multiple opportunities for connections (Honey, Pearson, & Schweingruber, 2014). *STEM Literacy* is "the knowledge and understanding of scientific and mathematical concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity for all students" (National Research Council 1996, p. 2). *T-STEM Academies* are secondary schools with a focus on increasing student enrollment for STEM fields by improving instruction and student achievement in science and math (Heinrich, 2013).

Implementing STEM: The Current Approach

STEM careers are essential for technology innovation and global competitiveness. Researchers (Langdon, McKittrick, Beede, Khan, & Doms, 2011) have presented conflicting conclusions regarding the effectiveness of problem-based instructional approaches including integration of STEM subjects in academia. For example, some believe subjects should not be taught in isolation because they are integrated in the workforce (Woodruff, 2013). Kirschner, Sweller, and Clark (2006) argued integrated learning is ineffective and unsuccessful due to the claimed failure of minimal guidance. Little research exists comparing the effectiveness of STEM programs and traditional instructional approaches in middle schools, so the results of this study will address this gap in the literature.

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For approximately 60 years, educational reform has addressed the area of STEM. In 1957, a competitive interest in technology and engineering increased in the United States with the launch of Russian satellite Sputnik (Lanius, Logsdon, & Smith, 2013). Americans emerged as a leader in STEM after President Eisenhower challenged citizens:

> The Soviet Union now has – in the combined category of scientists and engineers – a greater number than the United States. And it is producing graduates in these fields at a much faster rate. We need scientists in the ten years ahead. They (the President's advisors) say we need them by thousands more than we are now presently planning to have. The Federal government can deal with only part of this difficulty, but it must and will do its part. The task is a cooperative one. Federal, state, and local governments, and our entire citizenry must all do their share (Woodruff, 2013).

In 1958, the space program National Aeronautics and Space Association (NASA) was created. A decade after Apollo, the US emerged as a leader in the production of STEM employees with the number of students graduating engineering degrees. In the 1980s over 80,000 American earned college degrees in engineering (Adams, 1982). With the support of federal funds, education reform shifted the focus from memorization to scientific process and literacy (Woodruff, 2013). The Reagan Administration's National Commission on Excellence in Education published *A Nation at Risk* to further encourage education reform (Vinovskis, 2015). Texas was a leader in developing a Long-Range Plan for Technology (LRPT), adopted in November 1988 (Pignato, 2012). The LRPT aligns with the mission of Texas public education ensuring an engaging, relevant, and future-focused system of education for young learners.

In 1996, the National Science Education Standards refocused student centered science instruction with inquiry-based learning as a core philosophy (National Research Council, 1996). Meanwhile the National Council of Teachers of Mathematics outlined K-12 standards (Grouws, 1992). Lastly, the International Technology and Engineering Educators Association (1996) designed standards for technological literacy. All of these organizations combined to support STEM education reform and anticipating an increase in student readiness for STEM careers.

Today, United States leaders aim to be a global leader in STEM fields and innovation. According to Gomez and Albrecht (2013), ongoing research by the National Academies, the National Research Council, and the National Science Foundation findings are critical in addressing educational programming to position the United States as a leading country of global economies. Billions of government dollars are allocated to STEM education. The adequate preparation of students, teachers, and practitioners in STEM fields is critical to the economic development in the United States. Approximately

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$3 billion was designated to improve educational programs in an effort to increase student participation and employees in STEM fields (Kuenzi, 2008).

In spite of the investment in STEM education, the United States struggles to maintain a competitive edge. Many students fail to meet proficiency standards in science and mathematics in standardized testing. Often teachers lack knowledge in the subject matter, and may teach courses outside of their certification areas. Student achievement and degree attainments in math and science are below peers in other countries. Comparative to other nations, United States 15-year-olds ranked 28th in math and 24th in science. Among 24-year-olds earning degrees in math or science, the United States ranked 20th (Kuenzi, 2008). Of all degrees awarded in the United States, only 17% represent STEM fields. Postsecondary degree attainment doubled from 1960 to 2000 in the United States in STEM fields; however STEM degree attainment has since remained stagnant (Kuenzi, 2008).

President Obama renewed the challenge of scientific research and innovation in his 2009 State of the Union Address:

> We will not just meet, but we will exceed the level achieved at the height of the Space Race, through policies that invest in basic and applied research, create new incentives for private innovation, promote breakthroughs in energy and medicine, and improve education in math and science. Through this commitment, American students will move… from the middle to the top of the pack in science and math over the next decade – for we know that the nation that out-educates us today will out-compete us tomorrow. (Woodruff, 2013)

In 2010, President Obama's Council of Advisors on Science and Technology (PCAST) prepared a report providing a two-pronged strategy for improving K-12 STEM education: Prepare and inspire the next generation of students (Kennedy & Odell, 2014). The National Science and Technology Council's (NSTC) Committee on Science, Technology, Engineering, and Math Education (CoSTEM), established in 2011, was an attempt to coordinate policies and establish goals across federal agencies supporting STEM education.

A New Model: T-STEM Academies

The implementation of STEM varies. One example of such programs is a STEM initiative in Texas, titled T-STEM Academy. Texas Science, Technology, Engineering, and Mathematics Academies (T-STEM) utilize the T-STEM Blueprint (Texas Education Agency, n.d.). Campus leaders apply to Texas Education Agency (TEA) to earn the distinction of a designated T-STEM campus. In Texas, 92 T-

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STEM academies and 7 T-STEM technical assistance centers have received a budget totaling approximately $120 million (Young, House, Wang, Singleton, & Klopfenstein, 2011).

Originating in 2006, T-STEM academies have guidelines, or blueprints, including procedures for enrollment. The population must consist of at least 50% economically disadvantaged students, and academic performance is not a selection criteria (Young et al., 2011). T-STEM Academies serve all students of designated campuses; however, there is a priority on underrepresented populations including economically disadvantaged, at risk, and English language learners when selecting schools (Texas Education Agency, n.d.).

The curriculum in T-STEM Academies engages secondary students in STEM education. According to Van Overschelde (2013), the T-STEM curriculum provides challenges for students through activities, projects, and problem-based learning and promotes critical thinking, creativity, innovation, and real-world problem solving . Problem based learning allows the student to solve realistic problems that reflect the decisions and challenges people face very day rather than reading about facts and concepts that define a particular field of academic study and embedded technologies of T-STEM Academies support student goals expanding investigations, data collection, and data interpretation (Van Overschelde, 2013).

The blueprint is a required road map for T-STEM academies incorporating benchmarks and program expectations. Educators on each campus complete a self-assessment to determine a growth continuum of developing, implementing, mature, or role model. The blueprint is not exclusive to T-STEM schools, so it is a resource to increase rigor and college readiness for other schools as well. The document may provide assistance with developing business and college partnerships to increase career and college rigor and provides examples of critical thinking skills and problem solving. T-STEM academies benefit from network membership, professional development, events hosted by TEA and Educate Texas, and resources with best practices. T-STEM Academies have three memorandums of understanding including partnerships with an institution of higher education, a T-STEM Center, and a business partner (Texas Education Agency, n.d.).

There are seven T-STEM Centers located at Texas education centers (Region I STEM Center of South Texas and Region XIII Transformation Central Texas STEM Center) or higher education institutions (Aggie STEM Center, Center for STEM Education and Research University of Texas Dallas, Southeast Regional STEM Center UT Galveston, Ingenuity Center UT Tyler, and Texas Tech T-STEM Center). Each of the seven centers are similar, however they also offer areas of specialization (Morgan, Capraro, Capraro, & Nite, 2015). The centers provide services to the over ninety T-STEM Academies.

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T-STEM Centers have some funding available from TEA. Each T-STEM Academy has unique characteristics. However, the core program requirements include consistency in the areas of mission-driven leadership, culture and design, student outreach and retention, strategic alliances, and advancement and sustainability. The blueprint rubric contains seven benchmark areas (Texas Education Agency, n.d.).

Research Design: Quantitative, Causal-Comparative Study

The purpose of this causal-comparative quantitative study was to investigate campus performance rates as reported by the TEA in T-STEM Academies compared with campuses without T-STEM designation. The middle school campuses implementing a T-STEM program and schools in a state-identified comparison group that have not implemented the program were the participants in this study. Each of the five T-STEM campuses has a unique comparison group of 40 similar campuses. TEA officials established a list of 40 comparable campuses assessed under the state's accountability system. The campuses have similar student enrollment and demographics as defined by TEA. Campuses in the comparison group that do not have T-STEM academies are the control group, and the experimental group will include those five campuses that are T-STEM Academies (Texas Education Agency, 2015).

Five middle school T-STEM Academies provide adequate campus performance data in each of the tested subject areas as reported in the 2015 Federal System Safeguards Status Report (Texas Education Agency, 2015). The TEA 2015 Federal System Safeguards Status Report includes STAAR performance rates of reading, mathematics, writing, science, and social studies. The campus performance rate in each tested subject area is the percent of all students meeting the standard. The second group consists of middle schools in the comparison group, as provided by TEA, of each of the five T-STEM middle schools (Texas Education Agency, 2015). The variables in this study include middle school campuses and campus performance rates reflected on state accountability system reports. The data from these schools provided the comparison. The average score from each T-STEM school defined the known value in the one sample *t*-test. The comparison schools provided the mean data for comparison to the known value.

Findings

State of Texas Assessments of Academic Readiness (STAAR) campus performance rates as reported by TEA 2015 Federal Systems Safeguards Report were the data used for this study. The data from the state assessment allows educators to analyze student and campus performance. Campus data included all tested subject areas of reading, mathematics, writing, science, and social studies. Data included all students tested in each subject.

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The type of school, T-STEM or not, is the independent variable. The dependent variables are the campus passing rates in each subject area for the T-STEM schools and TEA comparable schools. It is appropriate to use a one-sample *t*-test to compare a known value to the means of dependent variables (Creswell, 2011; Huck, 2012). The average score from each T-STEM school defined the known value in the one sample *t*-test. The comparison schools provided the mean data for comparison to the known value. Used in this study was T-STEM schools (nominal data) and state assessment data (ratio data). A one-sample *t*-test compared nominal and ratio data. For each T-STEM campus, a one sample *t*-test was conducted for each subject area. This analysis occurred separately for each T-STEM school.

Math

Texas students in 6th, 7th, and 8th grade test in the area of mathematics. T-STEM Academies consistently had a higher percentage of students meeting standards on STAAR mathematics than campuses without T-STEM designation. Table 1 contains the results of the one sample *t*-test of STAAR mathematics campus performance rates between T-STEM Academies and campuses without T-STEM designation. T-STEM Academies had higher scores of 6% to 17% above campuses without T-STEM designation; however, in comparison group 2 the T-STEM Academy score was 11% less. The T-STEM Academy in comparison group 2 had the lowest passing rate (52%) of all the T-STEM Academies.

Table 1

One Sample t-Tests for STAAR Math

	Test Value	T	Df	Sig. (2-tailed)	Mean Difference
CG1	61	-5.336	39	0.000	-10.275
CG2	52	8.197	39	0.000	11.775
CG3	73	-6.422	39	0.000	-9.550
CG4	77	-4.045	39	0.000	-6.800
CG5	80	-8.928	39	0.000	-17.925

Science

Students in 8th grade tested in the area of STAAR science. Displayed in Table 2 are the results of the one sample *t*-test of science campus performance rates. There is a difference in campus performance rates on STAAR science between T-STEM Academies and campuses without T-STEM designation. The T-STEM Academy demonstrated 13% more students meeting the satisfactory standard in comparison to group five.

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Table 2

One Sample t-Tests for STAAR Science

	Test Value	T	Df	Sig. (2-tailed)	Mean Difference
CG1	43	1.376	39	0.177	2.750
CG2	56	1.407	39	0.167	2.250
CG3	55	1.045	39	0.303	2.125
CG4	67	-1.627	39	0.112	-3.175
CG5	69	-5.470	39	0.000	-13.800

Reading

Students enrolled in Texas public schools take the STAAR annually in multiple subjects from 3rd through 8th grades. Table 3 contains the results of the one sample *t*-test comparing the T-STEM known value and comparison group mean value of STAAR reading campus performance rates. There was a difference in campus performance rates on STAAR reading between T-STEM Academies and campuses without T-STEM for 6th, 7th, and 8th graders. In campuses without T-STEM designation, 4% to 9% more students met satisfactory standard in comparison group 1 and 3 than the T-STEM Academy. T-STEM Academies 4 and 5 had a 6% to 7% higher passing rate compared to campuses without T-STEM. Since two of the T-STEM Academies had better passing rates than the comparison groups and two had lower rates, the results were inconclusive.

Table 3

One Sample t-Tests for STAAR Reading

	Test Value	T	Df	Sig. (2-tailed)	Mean Difference
CG1	54	3.350	39	0.002	4.750
CG2	71	-1.560	39	0.127	-1.675
CG3	62	8.965	39	0.000	9.150
CG4	86	-6.311	39	0.000	-7.450
CG5	76	-4.723	39	0.000	-6.250

Writing

Texas students in 7th grade are tested in the area of writing. Table 4 contains the results of the one sample *t*-test of writing campus performance. Comparison Group 1 scored 4% less than the T-STEM Academy on the STAAR writing campus performance rate. Comparison Groups 2 and 3 scored between 5% and 10% higher than the respective T-STEM Academy. Comparison Group 4 scored 20% higher than the T-STEM Academy.

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Table 4

One Sample t-Tests for STAAR Writing

	Test Value	T	Df	Sig. (2-tailed)	Mean Difference
CG1	52	-2.581	39	0.014	-4.825
CG2	55	3.676	39	0.001	5.175
CG3	53	6.024	39	0.000	9.950
CG4	53	11.468	39	0.000	20.025
CG5	65	-1.607	39	0.116	-3.125

Social Studies

All Texas 8th grade students take the STAAR social studies assessment. Table 5 contains the results of the one sample *t*-test comparing the T-STEM known value and comparison group mean value of STAAR social studies campus performance rates. Campuses without T-STEM designation demonstrated 3% to 14% more students meeting satisfactory standard in three comparison groups than T-STEM Academies. Comparison Groups 1 and 3 scored between 3% and 6% higher than the respective T-STEM Academy. Comparison Group 4 scored 14 points higher than the T-STEM Academy.

Table 5

One Sample t-Tests for STAAR Social Studies

	Test Value	T	Df	Sig. (2-tailed)	Mean Difference
CG1	32	2.753	39	0.009	6.600
CG2	52	-1.286	39	0.206	-2.675
CG3	45	2.034	39	0.049	3.775
CG4	42	6.044	39	0.000	14.750
CG5	51	-.949	39	0.349	-2.375

Summary of All Subjects

Four of the five T-STEM Academies had a greater percentage of students meeting satisfactory standard in mathematics than the respective comparison group. In science, only one of the T-STEM Academies demonstrated a higher standard than its respective comparison group. Three of the four comparison groups had a greater percentage of students meeting standard in writing. There was an equal distribution of comparison in the area of reading. Two of the four T-STEM Academies scored higher in reading than the comparison groups. Comparison Group 1 and Comparison Group 3 scored higher in reading. No T-STEM Academies had a better student performance than the comparison groups in social studies.

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Overall, there was a difference of campus performance rates of T-STEM Academies and comparable campuses without T-STEM designation. T-STEM Academies had an increased percentage of student achievement in the areas of math and science. T-STEM Academies did not demonstrate a higher percentage of student achievement in the area of social studies.

Recommendations

Current researchers justified the need for educational reform including STEM education; however, there is little documentation evaluating the effectiveness of STEM programs on student achievement. As evidenced in the current literature, the need exists for improved instruction and student proficiency in STEM subjects. Educators need to prepare students for STEM fields in order to provide graduates with a competitive advantage in a global economy. U.S. President Barack Obama urged educational leaders and stakeholders to retain 100,000 STEM teachers over the next ten years and engage learners in STEM areas (US Department of Education, 2010). The results of this study may add to the current literature and assist educational stakeholders in making effective decisions for students and teachers.

Math

There was a difference is STAAR math rates between T-STEM Academies and campuses without T-STEM designation. Four T-STEM Academy rates had statistically significant higher passing rates than the comparison group on mathematics. In T-STEM Academies, the focus is on improving instruction and learning in the areas of math and science, and teachers at other campuses could benefit from some of the strategies. A recommendation is to involve school leaders from campuses without T-STEM in a professional learning community to share campus wide strategies that were successful in T-STEM Academies. Professional development could benefit teachers in T-STEM and non-T-STEM schools and should extend teacher instruction to integrated learning and PBL experiences. Through professional development, teacher leaders should share successful STEM education activities, including PBL lessons, which synthesize science, mathematics, engineering, and technologies and which encourage critical thinking, creativity, innovation, and relevant problem solving (Zollman, 2012). Finally, teachers and administrators at all schools should review the T-STEM blueprint as a resource that is not limited to T-STEM Academy usage.

Science

There was a difference is STAAR science scores between T-STEM Academies and campuses without T-STEM designation. All T-STEM Academies had statistically significant higher science

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passing rates than the respective comparison group. By design, T-STEM Academies focus on improving math and science achievement through effective instruction and integrated learning. Again, professional development focusing on collaboration, meaningful and relevant experiences, and problem-based inquiry is a recommendation. Another recommendation is for educators and administrators to review and utilize the T-STEM blueprint as a resource as it is not limited to T-STEM Academy usage.

Reading

There was a difference in STAAR reading rates between T-STEM Academies and campuses without T-STEM designation; however, two of the T-STEM Academies had better passing rates than the comparison groups and two had lower rates. Therefore, the results are inconclusive. Students in 8th grade must pass reading for promotion status. A recommendation is to increase vertical and horizontal alignment focused on effective implementation of Texas Essential Knowledge and Skills (TEKS), the state curriculum standards, in the area of reading. Teachers may share instructional strategies and methods within professional learning communities. District leaders may also strategically plan for the improvement of reading instruction, specifically for campuses with a focus on math and science.

Writing

There was a difference in STAAR writing rates between T-STEM Academies and campuses without T-STEM designation. Three of the comparison groups had statistically significant rates higher than their respective T-STEM Academies. A lesser emphasis on writing instruction may have been the result of increased focus on other areas such as math and science. District and campus leaders must explicitly state expectations for all TEKS, including writing. School leaders should identify teachers with instructional strengths in writing and utilize their strengths in professional development opportunities. Professional development to increase proficiency in writing and ideas for integration of writing instruction may apply in math and science instruction. Administrators should consider designing observation opportunities of teachers observing effective teachers. Another recommendation is to utilize available resources, such as T-STEM Centers, higher education partners, and business partners to increase student success in the area of writing.

Social Studies

There was a difference is STAAR social studies rates between T-STEM Academies and campuses without T-STEM designation. Three comparison group rates had statistically significant higher rates than the respective T-STEM campus. Although leaders may be eager to implement STEM programs, leaders remain accountable for state assessments in all subject areas. Math and science are

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priorities on most campuses, which may result in a lack of emphasis on social studies. A recommendation is for T-STEM leaders to collaborate for strategic planning of effective implementation of social studies TEKS. Educators in T-STEM Academies need to utilize available resources, such as T-STEM Centers, higher education partners, and business partners, to increase student success in the area of social studies.

Conclusions

Educational leaders may use this study for consideration of instructional programs. The data analysis supports T-STEM programs in the areas of math and science instruction. While educators may not implement a specific STEM education program, they could implement strategies, integrated learning, and PBL pedagogy similar to T-STEM implementation. The T-STEM blueprints are public information and available online.

Educators may benefit from programs that support STEM curriculum, teacher development, and student learning. Integrated studies are available through the support of federal government initiatives. Investments from agencies account for approximately 80% of STEM education federal funding in the President's budget request (Gonzalez & Kuenzi, 2012).

Students who experience early exposure to a STEM curriculum often follow it through high school (Thilmany, 2014). STEM pedagogy is rooted in interdisciplinary applied application of knowledge designed around a cooperative effort to provide students with comprehensive, relevant, real world applications. Sanders (2009) suggested STEM education includes approaches that explore teaching and learning among any two or more of the STEM subject areas. Merrill & Daugherty (2009) defined STEM education as a standards based, meta-discipline where all teachers teach an integrated approach to learning with content combined to a single study. STEM education supports a continuum of learning for students, educators, and business and community partners to provide learning pathways in technology driven careers. One benefit is that students can increase their knowledge of how things work through problem solving as well as enhance their technology skills. School districts nationwide select STEM courses as the framework for STEM based programs and curriculum.

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