Leadership of STEM: The PreK-12 Pathway

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This project addresses Absolute Priority 1 (Demonstrates a Rationale) and Absolute Priority 3 (Field-Initiated Innovations Promoting STEM and Computer Science).

A. Significance

A.1. National Significance

STEM education is at a crossroads. It has the potential to open doors for all students to develop and apply the knowledge and skills in STEM that are needed for college, careers and informed citizenship. Yet implementation of STEM largely takes the form of discrete, often disconnected courses in math and science, with minimal attention to engineering and technology and few learning experiences that integrate STEM across disciplines. The result is STEM implementation that lacks coherence; emphasizes secondary discipline-specific courses; and misses a broad swath of students who neither have access to nor are engaged in powerful STEM learning.

America faces this crossroads at a time when STEM occupations account for more than 50% of the employment in major industries (Fayer, Lacey, & Watson, 2017). Engineering and computer science make up the largest occupation groups in STEM and those with the most growth prospects (Fayer et al., 2017). America has an urgent need for STEM competence.

This need is particularly acute among underrepresented populations. Women fill 47% of all jobs, but only 23% of STEM jobs (Powers, 2017). African Americans and Latinos have STEM jobs (6%) at levels disproportionate to their overall representation in the workforce (11% and 14% respectively) (Beede et al., 2011).

Leadership of STEM: The PreK-12 Pathway (*PreK-12 STEM*) an initiative of the Community Training and Assistance Center (CTAC) and Tracy Unified School District (TUSD) responds directly to this need to develop STEM competence. It is a marked departure from the typical STEM implementation.

Instead of taking a piecemeal, episodic approach to STEM coursework, *PreK-12 STEM* provides students a STEM project-based curriculum that is engineering- and computer science-centered. It ensures that every student has a STEM learning trajectory that progresses through elementary, middle, and high school. Moreover, it increases the number of underrepresented students (girls, students of color and low-income students) engaged in STEM learning.

The national need to involve all children in STEM, particularly those historically underrepresented, is particularly relevant in the Tracy Unified School District. Tracy (CA) is emblematic of many communities nationwide that have undergone significant demographic changes during the past decade. Once a predominantly white middle class community, Tracy now has a primarily high needs student population. Student enrollment is 52% Latino, 6% African American, and 29% English Language Learners (ELL); 48% of TUSD students are female; 59% are living in poverty. All must be STEM competent.

PreK-12 STEM shows that being college- and career-ready means having the ability to apply deep knowledge of learning standards to real world contexts. Preparing every student for a STEM future necessitates rethinking the school curriculum, teaching methods, and partnerships with the employer community. *PreK-12 STEM* fundamentally changes the curriculum and prepares TUSD teachers to guide every student through project-based, interdisciplinary instruction that integrates engineering, computer science, math, science, and English language arts. It also mobilizes the major employers in STEM-related fields as partners in linking classroom instruction to industry standards and practices.

A.2. Promising Strategies

PreK-12 STEM focuses on three promising strategies: (1) **placing engineering and computer science at the center of student learning**. Differing from STEM initiatives that under-emphasize these areas (Nager & Atkinson, 2016; Education Development Center, 2013), *PreK-12 STEM* uses engineering and computer science as the levers to advance students' mastery of math, science, and English language arts; (2) **implementing STEM as a PreK-12 pathway**. *PreK-12 STEM* replaces disconnected offerings at the secondary level with a systematic approach to STEM learning that begins at the earliest grades and continues through high school; (3) **integrating STEM into the core curriculum to serve all students**. Rather than emphasize elective-based courses offerings that serve small subsets of students, *PreK-12 STEM* develops and prepares frontline educators to deliver an interdisciplinary curriculum that is available to *all* students, thereby ensuring equity in students' STEM learning experiences. These strategies are described below.

Placing engineering and computer science at the center of student learning. *PreK-12 STEM* changes the curriculum to emphasize engineering and computer science as the levers for interdisciplinary learning. These fields are regularly under-emphasized or overlooked in STEM, yet they are essential drivers of interdisciplinary learning on a PreK-12 spectrum.

Engineering is rooted in computational thinking, maximizing the use of different levels of abstraction and applying mathematical concepts to understand and solve problems more effectively. Engineering is an effective vehicle to engage students and teachers in computational thinking practices that require and apply computer science, math, science, and English language arts.

Computer science focuses on creating hardware for machines and products, designing software programs to drive machines and products, testing engineering designs in simulations, and making use of computer software to apply math and science concepts in the design process.

Engineering and computer science are a natural platform for project-based learning. They require the application of math and science concepts. Students use the engineering design process to design, construct, and test their solutions. They develop computer software and use coding skills to program their products. Students also learn and demonstrate essential workplace skills. They engage in a collaborative process, think creatively, learn to communicate their ideas clearly, and make critical decisions about moving forward within a project's design constructs.

Engineering and computer science also motivate students to learn. They enable students to define problems, develop projects that test solutions, and discover their agency in solving the problems, which motivates students to learn even more. Students also use the language of the field in authentic discussions about the projects which has been shown to increase academic language in English language learners (Feldman & Malagon, 2017). In short, the process of "design, build, test, evaluate" drives students to learn from their successes and failures, and see how their content learning from multiple STEM disciplines applies to real problems.

Implementing STEM as a PreK-12 pathway. In *PreK-12 STEM,* the foundation for STEM learning starts with carefully crafted learning opportunities at the earliest grades and expands in middle school and high school—in short, throughout a student's education. In this PreK-12 pathway, each set of learning experiences—both classroom and field-based—builds the foundation and expectations for the next set of learnings, charting a STEM learning trajectory aligned with standards.

Integrating STEM into the core curriculum to serve all students. Powerful STEM learning links and integrates multiple disciplines within the core curriculum. *PreK-12 STEM's* strategy is to engage all students in meaningful STEM learning, where alignment exists horizontally (across curriculum, instruction and assessment at all grade levels) and, as indicated above, vertically (across the PreK-12 span).

This emphasis places STEM in the core fabric of the schools and district, rather than as an isolated program. It also provides the framework for designing and teaching curriculum units around engineering (using the three-dimensional CA Science Standards, with a focus on the Engineering, Technology and Application of Science standards) and computer science (using CA Computer Science Standards)—the central disciplines of *PreK-12 STEM*'s interdisciplinary project-based learning approach.

A.3. Rationale

The project's rationale is grounded in and builds upon extensive evidence.

Engineering increases student learning through the application of concepts, knowledge, and skills. Engineering helps children to understand and apply their knowledge of math and science to real-world technologies and problems. Berland and colleagues (2013) found that students in an engineering design program demonstrated understandings of what engineers do (i.e., identify user needs, design, test, build and iterate) and improved their application of the relevant concepts, knowledge, and skills. Cantrell and colleagues (2006) found that engaging students in engineering curriculum activities diminishes achievement gaps in science for some student populations. Engineering is a cornerstone of *PreK-12 STEM.*

Starting STEM instruction early benefits students as learners. Many children demonstrate a clear readiness to engage in STEM learning at young ages. Starting STEM education early maximizes its benefits and effectiveness (McClure et al., 2017). Further, STEM education in early childhood education is associated with increased student learning in language and literacy. Scientific exploration exposes students to vocabulary directly related to their everyday life. Such exposure enhances language and vocabulary development, which is predicative of reading achievement. (Duncan et al., 2007; French, 2004). The project's PreK-12 strategy is predicated on beginning STEM instruction in the earliest grades.

Integrating STEM concepts and practices has positive effects on student learning. Such effects appear particularly strong for populations historically struggling in STEM classes and underrepresented in STEM programs in higher education and STEM professions (Honey, Pearson, & Schweingruber, 2014). Further, a recent meta-analysis (Becker & Park, 2011) shows that approaches which integrate all four STEM subjects produces the largest positive effect size on student learning. *PreK-12 STEM* integrates the STEM content areas on an interdisciplinary basis within the core curriculum.

Engaging in science discourse increases academic knowledge. When studying science, students utilize technical terms and languages to demonstrate how to conduct laboratory experiments, explain the process, and present reports. August and colleagues (2009) found that science instruction increased students' English oral proficiency through explicit vocabulary instruction, guided reading, and partnering with classmates who were more English proficient. *PreK-12 STEM* uses science as part of the interdisciplinary approach to students' mastery of academic language.

STEM project-based learning shows a positive impact on increasing student achievement and decreasing achievement gaps. Ross and colleagues (2001) compared schools that emphasize project-based learning, interdisciplinary studies, and real-world applications of academic content and community service to control schools. They found significantly greater achievement gains in all subject areas (i.e., language, math, science, and social studies) at the treatment schools.

Research studies show that students who are engaged in STEM project-based learning have higher gains in science achievement and perceptions of their abilities (Education Development Center, 2015), higher achievement in math (Han, Capraro, & Capraro, 2015; Scott, 2012), higher perceived efficacy (Chen, Hernandez, & Dong, 2015), and completion of more rigorous STEM programs (Scott, 2012). These outcomes are especially strong for the minority and low performing students who often started with lower domain-specific efficacy and achievement levels (Chen et al., 2015; Han et al., 2015). Project-based learning is an anchor of STEM content delivery in *PreK-12 STEM*.

A.4. Exceptional Approach

PreK-12 STEM is an exceptional approach at multiple levels.

First, it strengthens PreK-12 content development with an emphasis on core curricular linkages—across subject areas and aligned across grades—that support PreK-12 STEM education. It uses engineering and computer science as the lever for interdisciplinary learning and the mastery of state standards.

Second, it links interdisciplinary curriculum development with career development. This dual focus increases opportunities for *all* students and teachers to engage in problem- and project-based learning that is academically rigorous *and* builds understanding of STEM career options. This approach is critical for reaching and supporting students who are traditionally underrepresented in the STEM fields.

Third, it builds the professional capacity of teachers and principals—elementary, middle and high school—to support interdisciplinary STEM instruction and implement project-based learning. Taking this pathways approach to building STEM learning makes all grade levels and teachers responsible for providing the learning experiences necessary for student success.

PreK-12 STEM achieves these results through the leadership of TUSD, the STEM capacity building expertise of the Community Training and Assistance Center, the full engagement of corporate and governmental leaders in project based-learning through *PreK-12 STEM*'s Community Collaboratory, the specialized knowledge of the University of the Pacific's College of Engineering and Computer Science, and the evaluative expertise of Abt Associates.

When quality STEM education is the foundation of the core curriculum and teaching practices on a PreK-12 basis, students are both learning and applying new content. This PreK-12 pathway ensures participation by *all* students, not just those who traditionally gravitate toward these courses. The achievement of students increases as does their awareness of STEM fields, career opportunities and the role of STEM in the broader community. Demonstrating, evaluating and disseminating these strategies and results is the very definition of an exceptional approach.

B. Quality of the Project Design and Management Plan

B.1. Goals, Objectives, Outcomes, and Metrics

This project aims to (1) increase student academic growth in English language arts, math, and science, (2) increase the number of students who leave TUSD college- and career-ready, (3) develop and deliver a PreK-12 interdisciplinary STEM curriculum with project-based lessons centered on engineering and computer science, and (4) increase the rigor, relevance, and student engagement in STEM instruction. These goals will be measured as indicated in Table 1.

Table 1. PreK-12 STEM Goals, Objectives, Outcomes, Metrics, and Targets

GOAL	OBJECTIVE	OUTCOME	METRICS	TARGET
1. Increase student academic growth in English language arts, math, and science	Increase student performance in English language arts	Increase scores in English on the CA Assessment of Performance and Progress (CAASPP*) in grades 3-8 and 11	CAASPP Smarter Balanced Assessment Consortium (SBAC) Measured in Years 4, 5	10% increase each year in years 4, 5
	Increase student performance in math	Increase scores in math on the CAASPP in grades 3-8 and 11	CAASPP SBAC Measured in years 4, 5	10% increase each year in years 4, 5

GOAL	OBJECTIVE	OUTCOME	METRICS	TARGET
	Increase student performance in science	Increase scores in science on the California Science Test (CAST) in grades 5, 8 and 11	CAASPP CAST Measured in years 4, 5	10% increase each year in years 4, 5
2. Increase college- and career-readiness	Increase college- and career-readiness of TUSD students, with a particular focus on girls, students of color, and low-income students	Increase enrollment of high needs students in IB/AP STEM courses	IB/AP enrollment Measured in years 4, 5	20% increase each year in years 4, 5
		Increase test taking in IB/AP STEM courses by high needs students	IB/AP test taking Measured in years 4, 5	20% increase each year in years 4, 5
		Increase pass rates of high needs students in IB/AP STEM courses	IB/AP pass rate Measured in years 4, 5	10% increase each year in years 4, 5
		Increase completion of courses required for University of California/ California State University enrollment (A-G requirements*)	A-G requirements completed Measured in years 4, 5	10% increase each year in years 4, 5
3. Develop and deliver PreK-12 STEM curriculum	Develop and deliver project-based learning STEM curriculum centered on engineering and computer science	Develop and deliver STEM curriculum that meets the gold standard of the Buck Institute PBL Rubric	Buck Institute for Education PBL Project Design Rubric Measured in years 2-5	All units include all Essential Project Design Elements from Buck Institute for Education checklist
4. Increase rigor, relevance, and student engagement in STEM instruction	Use PLB units to increase relevance and rigor in STEM teaching, and student engagement in STEM interdisciplinary learning	Teachers provide instruction and engage student learning which shows evidence of students' mastery of content standards	International Center for Leadership in Education, Rigor, Relevance and Engagement rubrics Measured in years 2-5	90% of classrooms at Developed or Well-Developed after two years using STEM curriculum

*Courses from California high schools and online schools used to satisfy University of California (UC) and California State University admissions requirements must be approved by UC and appear on the institution's "a-g" course list. These are more rigorous than high school graduation requirements.

B.2. Management Plan

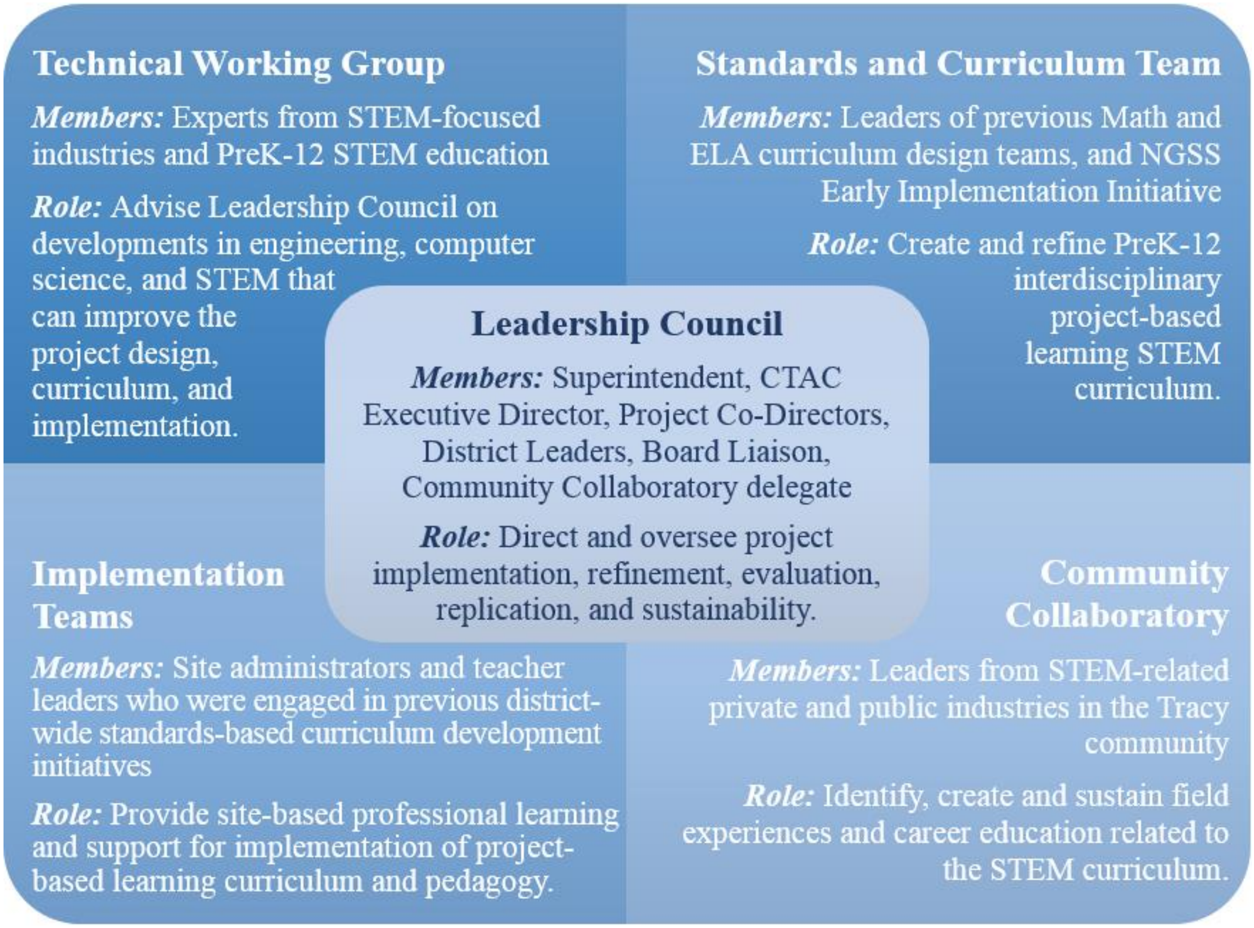
CTAC and TUSD are combining their collective strengths to transform STEM education and serve all of Tracy's children.

CTAC is a 39-year-old national non-profit organization with a demonstrated record of success in the fields of education and community development. Working at local, state, and national levels, CTAC achieves significant, long-term improvements in areas such as student achievement, educator effectiveness, and organizational capacity. CTAC has extensive experience conducting and evaluating projects in STEM and school to career pathways, and creating collaborations with public and private sector organizations. CTAC's work extends across the country in 43 states and the District of Columbia. Additionally, CTAC has significant national experience in managing large-scale school district projects, serving as the lead and fiscal agent on numerous US Department of Education grants.

TUSD, based in California's Central Valley, has implemented three district-wide initiatives since 2014 to drive standards-based instruction in the Common Core and Next Generation Science Standards. For example, in the K-8 NGSS Early Implementation Initiative, TUSD was one of eight districts to lead California in implementing the Next Generation Science Standards. These initiatives create the foundation for this proposal, providing the committed administrative and teacher leadership, project expertise, statewide network, and district-wide awareness of STEM ideas. *PreK-12 STEM* follows a year and a half of groundwork by TUSD and CTAC to harness the Tracy community and key TUSD personnel in a project that is endorsed by local and regional educational institutions, industry, and community leaders.

The management plan is led and implemented by a Leadership Council with four integrated, complementary teams.

Figure 1. Management Structure



Leadership Council. The Leadership Council (LeaderC) oversees *PreK-12 STEM.* It is responsible for project direction, implementation and improvements, and the accountability of the entire effort. It also connects district and community resources. The Council includes leaders from CTAC and TUSD (including the district Superintendent and a school board member) and the Community Collaboratory (the stakeholder group of local industry leaders, described below). The Project Co-Directors serve on the Council and support the groups and teams below.

Technical Working Group. The Technical Working Group (TWG) advises the Leadership Team on developments in engineering, computer science and STEM education that can improve the project design, curriculum, and implementation. The TWG includes experts from STEMfocused industries (a Fortune 200 corporation and a national laboratory) and PreK-12 STEM education.

Standards and Curriculum Team. This team (StdCurrT) includes teacher leaders from TUSD's extant pool of standards experts who designed Tracy's curriculum in, respectively, math, science, and English language arts. In *PreK-12 STEM*, this team rethinks and fundamentally changes the PreK-12 curriculum to emphasize interdisciplinary and project-based STEM learning. The team also works with leaders from the Community Collaboratory to embed industry knowledge of engineering and computer science *and* field-based learning experiences within the STEM curriculum. This team refines the curriculum based on feedback from the formative evaluation, the Leadership Council, the Collaboratory and the Implementation Teams at the treatment sites.

Implementation Teams. These teams (ImplemT) guide implementation of the new STEM curriculum at the school sites. They provide site staff with professional learning to understand and effectively implement the new curriculum. Building on TUSD efforts to develop teacher leaders and improve administrators' leadership of instruction, each school's Implementation Team—convened by the site administrator—includes teacher leaders who were engaged in previous district-wide standards-based curriculum development initiatives. Each Implementation Team is assisted by the Standards and Curriculum Team and the Leadership Council.

Community Collaboratory. The Community Collaboratory (Collab) includes the leaders from STEM-related industries (health, agribusiness, manufacturing, technology, and civil engineering) in the Tracy community. These leaders advise and consult with the Standards and Curriculum Team during curriculum development and revision work. The entire Collaboratory identifies, creates and sustains field experiences and career education related to the STEM curriculum. The Collaboratory is dedicated to collaborating across industry lines to spur STEM educational innovation that benefits Tracy's students.

This management structure assures the effective development, implementation and ongoing refinement of the PreK-12 STEM pathway.

Cohorts Defined. All 17 schools in TUSD participate in the initiative in three successive cohorts. Cohort 1 includes sites with grades PreK-5 and begins implementation in school year 2019-20. Cohort 2 includes sites with grades PreK-8, 6-8, and 9-12 and begins implementation in school year 2020-21. Cohort 3 includes all sites held out as comparison sites, with grades PreK-12, and begins implementation in school year 2022-23.

Table 2. Cohort I, II and III Schools

Cohort and Type of School (Treatment or Comparison)	School Year					Number of Schools by Grade Levels Served					
	2018-19	2019-20	2020-21	2021-22	2022-23	PreK-5	PreK-8	6-8	9-12	11-12	Total
Cohort I TUSD Schools		T	T	T	T	6					6
Cohort II TUSD Schools			T	T	T		3	1	2		6
Cohort III TUSD Schools		C	C	C	T	1	1	1	1	1	5
"T" indicates Treatment Schools "C" indicates Comparison Schools											

Management Plan Milestones and Activities. The Leadership Council, working groups and teams, and external evaluator are implementing *PreK-12 STEM* to address and meet 7 essential milestones, as delineated below.

Table 3. Management Plan Milestones and Activities

Activities	Begin Date	End Date	Responsible
Milestone 1: Operationalize the PreK-12 STEM organizational structure.			
Convene the Leadership Council and communicate how it will operate throughout the project	Jan 2019	Feb 2019	LeaderC
Confirm staffing, roles and responsibilities, and deliverables for the Technical Working Group, Standards and Curriculum Team, Implementation Team and Community Collaboratory	Jan 2019	Feb 2019	LeaderC
Build a detailed operational plan for each year of the project	Feb 2019	Mar 2019	LeaderC
Create a project implementation tracking system	Feb 2019	May 2019	LeaderC

Activities	Begin Date	End Date	Responsible
Kickoff the project with all established groups and teams	Feb 2019	Feb 2019	LeaderC, TWG, StdCurrT, Collab
Operationalize the Leadership Council (*every other month years 1-3 and quarterly thereafter*), Technical Working Group (*twice annually*), Standards and Curriculum Team (*monthly*), Implementation Team (*monthly*), Community Collaboratory (*quarterly*) to ensure timely, cohesive and strategic decisions for project implementation	Feb 2019	Sep 2023	LeaderC, TWG, StdCurrT, ImplemT, Collab
Milestone 2: Develop PreK-12 interdisciplinary STEM curriculum for each grade, to be implemented by cohort. Cohort 1 (C1), Cohort 2 (C2)			
Develop STEM project-based learning curriculum PreK-5, ready for Cohort 1	Mar 2019	Jun 2019	StdCurrT, Collab
Develop STEM project-based learning curriculum 6-12, ready for Cohort 2	Jan 2020	Jun 2020	StdCurrT, Collab
Revise the curriculum, on an ongoing basis, based on formative feedback	C1: Aug 2020 C2: Aug 2021	C1: May 2023 C2: May 2023	LeaderC, StdCurrT, Collab
Milestone 3: Implement STEM curriculum at school sites by cohort. Cohort 1 (C1), Cohort 2 (C2), Cohort 3 (C3)			
Develop and implement school site plans to address project-based learning requirements: materials, equipment, schedule, learning space arrangements	C1: Apr 2019 C2: Apr 2020 C3: Apr 2022	C1: Jul 2019 C2: Jul 2020 C3: Jul 2022	LeaderC, ImplemT
Provide professional development and training for Implementation Teams	C1: Jun 2019 C2: Jun 2020 C3: Jun 2022	C1: Aug 2019 C2: Aug 2020 C3: Aug 2022	LeaderC
Provide site administrator training on classroom observation ensuring inter-rater reliability across cohorts	C1: Jun 2019 C2: Jun 2020 C3: Jun 2022	C1: Aug 2019 C2: Aug 2020 C3: Aug 2022	LeaderC
Initiate implementation of STEM curriculum at school sites by cohort	C1: Aug 2019 C2: Aug 2020 C3: Aug 2022	C1: May 2020 C2: May 2021 C3: May 2023	ImplemT
Refine the implementation of STEM curriculum, on an ongoing basis, based on formative feedback	C1: Aug 2020 C2: Aug 2021	C1: May 2023 C2: May 2023	ImplemT
Milestone 4: Engage private and public sector partners in the development, delivery, and refinement of PreK-12 STEM educational experiences.			
Coalesce the Community Collaboratory	Feb 2019	Feb 2019	LeaderC, Collab

Activities	Begin Date	End Date	Responsible
Advise and consult with the Standards and Curriculum Team during curriculum development and revision	Feb 2019	Sep 2023	LeaderC, Collab, StdCurrT
Identify, create and sustain career education and field experiences related to the STEM curriculum	Mar 2019	Sep 2023	LeaderC, Collab
Ensure alignment of interdisciplinary curriculum with industry standards and experiences	Jun 2019	Sep 2023	LeaderC, Collab, StdCurrT
Milestone 5: Provide formative assessments to determine fidelity of implementation and progress towards project goals. Cohort 1 (C1), Cohort 2 (C2), Cohort 3 (C3)			
Conduct interviews and focus groups, 2 times per school year, with teachers, administrators, parents, students, and Collaboratory partners	Oct 2019 May 2020	Oct 2022 May 2023	CTAC
Administer surveys, 3 times per year, with teachers, administrators, parents, and students	Oct 2019 Jan 2020 May 2020	Oct 2022 Jan 2023 May 2023	CTAC
Conduct comparative analyses of in district, *individual* student growth using SBAC and CAST	Sep 2021	Sep 2023	LeaderC, CTAC
Analyze student progress related to college- and career-readiness	Sep 2021	Sep 2023	LeaderC, CTAC
Analyze the project-based content of the interdisciplinary units and their integration into the core curriculum	Jul 2019	Sep 2023	LeaderC, CTAC, Collab
Review feedback every 2 months from site administrators on outcomes from classroom observations related to rigor, relevance, and engagement	C1: Oct 2019 C2: Oct 2020 C3: Oct 2022	C1: May 2023 C2: May 2023 C3: May 2023	LeaderC, ImplemT
Share feedback for purposes of continuous improvement with the Leadership Council, TWG, teams, and the Community Collaboratory	Oct 2019	Sep 2023	LeaderC, Abt, CTAC
Milestone 6: Conduct QED with independent evaluator, to analyze the impact of PreK-12 STEM.			
Finalize study design (impact and implementation evaluations) that meet WWC standards with reservations	Oct 2018	Jun 2019	Abt
Obtain Abt IRB approval	Jun 2019	Aug 2019	Abt
Design and pilot implementation fidelity measures for each key component of logic model	Jun 2019	Sep 2019	Abt, CTAC
Collect and analyze fidelity data on Cohort 1 treatment schools (in 2019-20)	Sep 2019	Jul 2020	Abt, CTAC
Collect and analyze fidelity data on Cohort 1 and Cohort 2 treatment schools (in 2020-21)	Sep 2020	Jul 2021	Abt, CTAC

Activities	Begin Date	End Date	Responsible
Collect and analyze fidelity data on Cohort 1 and Cohort 2 treatment schools (in 2021-22)	Sep 2021	Jul 2022	Abt, CTAC
Identify pool of comparison schools, collect baseline achievement data for Cohort 1 treatment and comparison schools, and create 4:1 matched sample (using data from spring 2019, 2018, and 2017 state testing)	Jan 2022	Jun 2022	Abt
Identify pool of comparison schools, collect baseline achievement data for Cohort 2 treatment and comparison schools, and create 4:1 matched sample (using data from spring 2020, 2019, 2018 and 2017 state testing)	Jan 2022	Jun 2022	Abt
Collect academic outcome data for Cohort 1 schools and matched comparisons from spring 2020, spring 2021, and spring 2022 testing	Nov 2022	Dec 2022	Abt
Collect academic outcome data for Cohort 2 schools and matched comparisons from spring 2021 and spring 2022 testing	Nov 2022	Dec 2022	Abt
Conduct final impact analysis using Cohort 1 and Cohort 2 schools (all treatment and all baseline years)	Jan 2023	May 2023	Abt
Conduct implementation study analysis for Cohorts 1 and 2	Aug 2019	Sep 2023	Abt, CTAC
Collaborate with external evaluator to use the formative data analysis to inform and refine the implementation for each cohort receiving treatment	Oct 2020	Oct 2023	LeaderC, Abt, CTAC
Submit final report on impacts (1-3 years) and fidelity (1-3 years)	--	Sep 2023	Abt
Milestone 7: Document and disseminate findings related to the three research questions.			
Create and share on the project portal, a prototype for the engineering- and computer science-centered curriculum and instructional approach	May 2022	Sep 2023	LeaderC
Share implementation collateral, communications, and key learnings to advance and accelerate others work in this area	May 2022	Sep 2023	LeaderC
Build and share a cost model for scaling up a prototype	Jan 2023	Sep 2023	LeaderC
Share findings and key learnings with STEM-related networks, leadership associations, and educational research community, both nationally and in California	Oct 2022	Sep 2023	LeaderC, TWG
Note: LeaderC = Leadership Council; TWG = Technology Working Group; StdCurrT = Standards and Curriculum Team; ImplemT = Implementation Team; Collab = Community Collaboratory, Abt = Independent Evaluator			

Key Personnel. Table 4 below describes the key project personnel. Resumes for all personnel are included in Appendix B.

Table 4. Key Personnel

Name and Title	Project Responsibilities	Relevant Experience
William Slotnik, Executive Director, CTAC	• Provides oversight of project design, implementation, and refinement • Coordinates all project staff • Guides continuous improvements based on formative assessment	• Proven track record in strengthening instructional capacity of educators with demonstrable increases in student academic growth • Expert in areas such as school improvement, STEM curriculum, performance-based compensation, and multi-sector collaboration
Scott Reynolds, Project Co-Director, CTAC	• Manages and monitors daily implementation of the initiative to ensure all milestones and timelines are met. • Supervises the curriculum development, training, and roll-out	• Guided multiple school and district level initiatives on STEM and project-based learning • Trained 35 states on use of STEM instructional goal setting • National recognition for excellence in science teaching
Margaret Sharp, Ed.D., Senior Associate, National School Reform and Chief Academic Officer, CTAC	• Conducts interviews and focus groups of *PreK-12 STEM* participants and partners • Conducts survey analysis • Assists in development and delivery of training programs	• Demonstrated expertise in project-based learning and interdisciplinary curriculum development • Served as Chief Academic Officer in two school districts
Brian Stephens, Ed.D., Superintendent, TUSD	• Oversees all aspects of project implementation, including fiscal, human resources, impact, and outcomes	• Over 30 years of experience in public education, including 26 years as a school administrator • Oversees district of more than 15,500 students and nearly 2,000 certificated, classified and administrative staff

Name and Title	Project Responsibilities	Relevant Experience
Debra Schneider, Ph.D., Project Co-Director, TUSD	• Manages and monitors daily implementation of the initiative to ensure all milestones and timelines are met. • Supervises the curriculum development, training, and roll-out	• Directed $1.4 million K-8 NGSS Early Implementation Initiative • More than 15 years' experience writing published curriculum and pedagogy
Melissa Beattie, Staff Development Director, TUSD	• Coordinates and supports professional development with technical assistance providers and external experts	• Provides oversight of all TUSD teacher preparation programs • Expertise in developing and implementing professional learning plans, on-going coaching training, and supervision of certificated and classified staff.
Sarah Sahni, Ph.D. Associate, Social & Economic Policy, Abt Associates	• Directs the independent evaluation • Ensures that data collection instruments meet the needs of the evaluation • Completes analyses as appropriate	• Leadership experience in conducting systematic reviews of evaluation rigor and findings for the U.S. Department of Education and U.S. Department of Labor • Certified What Works Clearinghouse reviewer and a recognized expert technical reviewer of evaluation design, research methods, and findings.

B.3. Performance Feedback and Continuous Improvement

CTAC manages the project in partnership with the district. In direct support of the Leadership Council and the overall project management structure, CTAC monitors program implementation and provides continuous feedback based on the analysis of both qualitative and quantitative data. Consistent with and complementing the evaluation design, performance feedback and continuous improvement focus on:

Fidelity of implementation of *PreK-12 STEM*. CTAC is creating a tracking system that documents and examines fidelity to the goals, deliverables and timelines in the project management plan. As delineated above in B.2, CTAC is regularly conducting, analyzing and sharing the results from individual interviews, focus groups and surveys of each cohort of treatment schools—including teachers, administrators, parents, and students in grades 4-12, as well as industry leaders from the Community Collaboratory.

These analyses help ensure that *PreK-12 STEM* is on track and that feedback contributes to continuous improvements. Further, they enable the Leadership Council and the TWG to examine the ongoing effectiveness—and the factors contributing to or impeding that effectiveness—of the interdisciplinary STEM curriculum and the field-based learning experiences, the vertical and horizontal alignment of the PreK-12 pathway, and the ability of the project to serve all students.

Progress towards specific project goals. CTAC and TUSD also conduct analyses to determine progress towards project goals, including:

- *Increasing student academic growth*. CTAC conducts comparative analyses of in district, *individual* student growth using SBAC and CAST as the performance measures.
- *Increasing college- and career-readiness*. CTAC analyzes student progress, with a particular focus on the progress of high needs students.
- *Developing and delivering the PreK-12 STEM curriculum.* Both CTAC and TUSD analyze the project-based content of the interdisciplinary units and their integration into the core curriculum.
- *Increasing rigor, relevance and student engagement of STEM instruction*. Trained TUSD site administrators regularly observe and rate teachers' pedagogical practices, with a particular focus on the use of engineering and computer science as levers for robust STEM learning.

Feedback and Continuous Improvement. As Figure 1. Management Structure and Table 3. Management Plan Milestones and Activities show, the project design and overall structure intentionally provide district leaders and partners with timely and comprehensive pictures of the progress of the project. The Leadership Council, TWG, teams, and the Community Collaboratory all have the information needed in real time to make informed, responsive improvements on an ongoing basis. Moreover, by carefully studying the ongoing fidelity and impact of implementation, the project is able to identify factors and challenges relevant to districts interested in replicating and scaling *PreK-12 STEM.*

B.4. Broad Dissemination Supports Further Development and Replication

CTAC and TUSD are committed to ensuring that the lessons learned and results from *PreK-12 STEM* benefit school districts, other educational practitioners and researchers. The dissemination mechanisms have several components, including:

Online Portal. CTAC is establishing and hosting a dedicated project website, providing open source materials to interested practitioners, policy makers and researchers. This resource platform is intended to include artifacts, hands-on implementation guides, FAQs, and formative and summative evaluation reports. The goal is to provide information and online assistance related to using engineering and computer science to drive interdisciplinary STEM education, implementing STEM on a PreK-12 pathway, and integrating STEM within the core curriculum to serve all students.

California. With 11,725 public and charter schools, and a population that is 76% students of color, California is a particular focus of *PreK-12 STEM's* dissemination efforts. Building on TUSD's state leadership experience, CTAC and TUSD focus on providing presentations and webinars targeted to California STEM-related networks and leadership associations.

National. Building on CTAC's leadership experience, dissemination also focuses on providing presentations and webinars to both national STEM-specific associations and networks

Figure 2. Dissemination: Networks and Associations

California

- California STEM Network
- NGSS Early Implementation Initiative
- North Central Valley STEM Network
- STEMconnector
- Californians Dedicated to Education Foundation
- Association of California School Administrators

National

- National Council of Teachers of Mathematics
- National Assoc. for Research in Science Teaching
- National Science Teachers Association
- American Society of Engineering Education
- American STEM Alliance Network Improvement Community
- Comprehensive Centers
- Regional Educational Laboratories
- Community for Discovery Research in Education
- Knowledge Alliance

that advance the use of evidence and capacity building in education. This includes the alliance of 20 leading educational research organizations (CTAC's executive director has served for four years on its Executive Committee).

Track Record. CTAC has a demonstrated track record of success in establishing and using mechanisms to support the development and large scale replication of promising initiatives. For example, CTAC introduced and showed the effectiveness of Student Learning Objectives (SLO's) in a groundbreaking initiative in Denver, CO, and subsequently helped Austin, TX and Charlotte-Mecklenburg, NC to implement SLO's at an increasingly higher level of science. CTAC then assisted the U.S. Department of Education to adopt, and more than 40 states and several thousand school districts to embrace, SLO's as a model for new educator evaluation systems.

CTAC and TUSD are drawing from these experiences and using the above-mechanisms to ensure an effective dissemination of the project's lessons and results.

C. Quality of the Project Evaluation

Abt Associates, a nationally recognized research organization with extensive experience conducting field tests of educational interventions, is conducting an independent evaluation of *PreK-12 STEM* that addresses key research questions about impacts of the program on students' academic achievement and about the quality and fidelity of program implementation:

RQ1. What is the effect of *PreK-12 STEM* on the academic achievement (in math, English language arts, and science) of students in grades 3 – 12?

RQ2. What is the level of fidelity of implementation of *PreK-12 STEM* in schools that have been implementing the intervention for one, two and three years?

RQ3. What are the factors that appear to facilitate effective implementation of the *PreK-12 STEM* and what are key challenges to be addressed to support future replication?

During the study period, the full *PreK-12 STEM* pathway will be implemented by cohort in 12 of the 17 schools. The first cohort of schools is 6 of the district K-5 schools, which will begin implementation in 2019-20. The second cohort of schools, including three K-8 schools, one 6-8 school, and two high schools, begins implementation in 2020-21. In the fifth year of the grant, *PreK-12 STEM* is implemented into the remaining five schools in the district. The impact and aligned implementation study occurs during school years 2019-20 through 2021-22, based on the combined sample of schools from Cohorts 1 and 2. During the last year of the grant, the grantee will be involved in formalizing the training resources and materials for *PreK-12 STEM* across the full grade range, so that other districts can implement the same intervention going forward.

The project will finalize the curriculum materials, technology supports, and teacher training on a rolling basis, so that all curriculum materials, technology supports, and teacher training procedures are in place prior to the full-scale impact study.

The *PreK-12 STEM* project encompasses instructional and structural changes in the school district at all grade levels. The refinement of the full set of supports (curricula, technology, teacher PD) occurs on a rolling basis, aligned with the schedule for bringing different grade levels into the impact study sample. In the first 2 years of the grant, the grantee team begins the development of the materials across the PreK-5 grade range for implementation in year 2 (school year 2019-20). Curriculum development for grades 6-12 takes place in year 2, for implementation in year 3 (school year 2020-21). Refinement and revision of PreK-12 curriculum continues each year. During year 1 of the grant, Abt finalizes the evaluation design and collaborates with the grantee to develop and pilot an implementation fidelity measure for the project.

The impact evaluation will be designed to produce evidence of PreK-12 STEM's effectiveness that meets What Works Clearinghouse Standards With Reservations (C.1.)

Abt will conduct a rigorous test of the impacts of the *PreK-12 STEM*, using a quasi-experimental design that will *Meet WWC Standards with Reservations*. Abt will compare achievement of students in schools in Tracy USD that are implementing the STEM with a sample of similar schools that are not part of the initiative, including schools in Tracy where the pathway has not yet been rolled out and similar schools in neighboring districts. Abt will estimate differences in the levels of average school-level achievement over time of treatment and comparison schools using a Comparative Interrupted Time Series analysis (Bloom, 2003) that takes advantage of having multiple years of data on achievement before and after the introduction of the STEM curriculum. For each school in the treatment group, Abt will identify four comparison schools that are (a) the same grade configuration (e.g., elementary, middle, high school) and (b) have similar baseline achievement levels and demographic characteristics and can be shown to satisfy WWC standards for baseline equivalence.

Appropriate and rigorous methods will answer impact research questions.

A CITS approach is used to address research questions 1 and 2. This approach controls for baseline achievement levels and trends, as well as other baseline characteristics when comparing outcomes of students in treatment schools to those of students attending comparison schools. The outcome data for the analyses is comprised of grade-within-school-average achievement scores for each tested grade's (grades 3-8 and 11 for math and ELA) outcomes for 3 years for the Cohort 1 schools and 2 years for the Cohort 2 schools. The baseline data consists of average school achievement from three years (Cohort 2 schools) or four years (Cohort 1 schools) before the implementation of the project in that school. Outcome data from the different grades is standardized (z-scored) prior to analysis as described in Price (2013).

In the CITS design, the "interruption" is the introduction of the *PreK-12 STEM* intervention in the treatment schools, and the "time series" is comprised of the multiple years of outcome data before and after the "interruption." The estimation of the intervention impact in this design comes from comparing the pre-post difference in outcomes in treatment schools (accounting for any trends in the outcome in the pre-treatment years), to the same difference in the comparison schools. More than 15 CITS designs have or are being used in the i3 and EIR grant programs

(Price et al., 2015). Design replication studies have shown that CITS can perform well in replicating impact estimates from randomized controlled trials (Somers et al., 2013; St. Clair et al., 2014; Jacob et al., 2016). When a CITS design is implemented and reported to align with WWC standards, it is eligible to meet WWC Group Design Standards with Reservations.

Sample and Power. The impact study includes 12 treatment and 48 comparison schools. In the TUSD schools, the intervention begins school year (SY) 2019-20 for Cohort 1 schools, in SY 2020-21 for Cohort 2 schools. The impact evaluation utilizes outcome data only through SY 2021-22, and the remaining 5 TUSD schools act as comparison schools for the treatment schools that implement in the earlier cohorts. Forty-three comparison schools are selected from other California schools outside of TUSD. The numbers of treatment and comparison schools and the treatment and pre-treatment years for which outcome measures (grade-within schools average achievement) are depicted in Appendix E, Table 1. The estimated MDE for the intervention effect on ELA and math achievement outcomes is 0.18 student-level standard deviation units of the outcomes. The assumptions are: Cohort 1 schools will have 3 pre-treatment and 3 post-treatment outcome measurements; Cohort 2 schools will have 4 pre-treatment and 2 post-treatment outcome measurements. The primary analysis—impact averaged over all measured grades and schools—will produce an impact estimate where the treatment effect is averaged over treatment years 1, 2, and 3. For the math/ELA outcomes, grade-within-school average achievement scores will be obtained for each of 7 grades (grades 3-8, and 11) and for 6 years (SY 2016-17 through 2021-22), and 60 schools (12 treatment, 48 comparison) the impact analysis will be based on (7 x 6 x 60 =) 2,520 grade-within-school average achievement measurements. (The expected MDE for math/ELA achievement outcomes were estimated by applying the planned impact model for the current study to a subset of data from a prior study with achievement scores from grades 3-8 over a 6- year period (see Appendix E).)

The evaluation will provide valid and reliable data on relevant outcomes (C.3.)

As laid out in the program logic model (Appendix D), the goal of *PreK-12 STEM* is to improve (a) student achievement in math, science and language arts across the grade range. Because all of the achievement measures are standardized tests, the WWC assumes the outcomes meet all of the WWC outcome standards. All of the outcome data are obtained from districts—from Tracy USD for its school test data and district websites for the comparison schools outside of Tracy. The study's achievement outcomes are scores on the state-administered Smarter Balanced Assessments for math and English language arts, given every year in grades 3 – 8 and 11. (The study may be able to use data from a new California state science test, the CAST, which is being piloted in 2017-18. The test is planned to be administered in grades 5, 8 and high school.)

The CITS design requires multiple years of baseline data on schools on the same test as the outcome; for the Smarter Balanced Assessments outcomes, baseline data are available in both treatment and comparison schools for multiple years prior to the implementation of *PreK-12 STEM* in the treatment schools. If CAST data are available only for 1 baseline year before the intervention, Abt will use an ANCOVA approach that will provide less power but will still meet WWC standards with reservations.

The implementation evaluation will clearly articulate the key components, mediators, and outcomes, as well as the thresholds for acceptable implementation of each component (C.4.)

The logic model for *PreK-12 STEM* (Appendix D) articulates the program's key components, mediators, and outcomes for the initiative. During the first year, Abt collaborates with CTAC to develop appropriate and systematic measures of fidelity of implementation for each of the key components of the project logic model. As part of this development process, Abt helps the grantee establish thresholds for what constitutes adequate fidelity at the school level and at the sample level for each measure.

The evaluation will provide guidance about effective strategies suitable for replication or testing in other settings (C.2.)

Across the four years of implementation, Abt collaborates with CTAC in conducting a rich implementation study of *PreK-12 STEM.* The implementation study includes interviews and focus groups with key constituencies two times per year, and surveys three times per year, to identify factors and challenges affecting the successful implementation of the initiative. One of the goals of this more qualitative implementation study is to derive lessons for future replication and scaling of the initiative in other districts.