Table of Contents

Scaling an innovative *STEM And Computing Education Support (STEMACES)* Model for Improved Science Learning

Sonoma State University (SSU), a public institution of higher education with non-profit and Hispanic Serving Institution (HSI) status, in partnership with Angelo State University (also a public university with HSI status), will expand opportunities in STEM+C (Science, Technology, Engineering, Mathematics and Computing) for at least 2000 rural, under-represented and high-need, eighth-grade students in two states: California and Texas. We propose to use a theory of action to scale a model of what works to improve student science outcomes based on moderate evidence (Schneider et al., 2022 and Newman et al., 2012.) The theory of action implements three model components with fidelity: a STEM curriculum, Professional Development (PD), and Teacher Supports. To these model components, we will add innovative Technology, Engineering, and Coding (TEC) elements from SSU's ninth-grade (*Learning by Making* or *LbyM*) curriculum; include TEC elements within teacher PD and student support; and develop and validate a generalized Computational Thinking (CT) assessment for evaluating TEC-embedded STEM student learning. Together, the three model elements and our proposed innovations comprise the STEM And Computing Education Support (*STEMACES*) scaling model. The main goals of *STEMACES* are to improve high-need rural student achievement in science while expanding engagement in these underserved communities with TEC tools and activities that include Computational Thinking (CT). Over the course of five years, we will target at least 40 teachers, 40 middle schools, and 800 students to participate in the *STEMACES* research program, which has been designed by our evaluation partners at WestEd to provide strong evidence of effectiveness through randomized control trials at the school level. The population of targeted schools will be high-needs and also average at least 40% Hispanic students, 30% White students, and 90% will

have district locale codes that are rural. In this proposal, we define high-need student populations as those with at least 50% eligibility for Free or Reduced-Price Lunch (FRPL). This is a reasonable proxy for youth from families living at or below the poverty line. Throughout this proposal we use the federal terminology "Hispanic" to refer to culturally diverse populations that would normally prefer to be referred to by their nationality or heritage. As such, "Hispanic" does not capture the full diversity of our targeted students. Hispanic residents often identify as "Latino" or Mexican-American because they are overwhelmingly of Latin American heritage, and in California, primarily originate from Mexico (PPIC2022).

The *STEMACES* model incorporates elements of the *LbyM* ninth-grade STEM+C curriculum developed through SSU's i3 and EIR-funded Early Phase projects for high-need rural students in California. *LbyM* is the first STEM+C curriculum developed specifically to address challenges faced by rural underserved and under-resourced schools, including lack of access to affordable technology and teachers who are not skilled in TEC (Kormos and Wisdom 2021). The research study done at the end of the i3-funded *LbyM* program has met What Works Clearinghouse (WWC) standards with reservations (Li et al., 2018; WWC Review 2022), demonstrating improvement in both science and mathematics. *STEMACES* also leverages *LbyM*'s innovative Open Educational Resource (OER) Web App (Cominsky et al., 2023) greatly reducing the cost for adoption as specialized computers no longer need to be provided and required tech support at the schools is minimal. Incorporating innovative TEC elements from *LbyM* into *STEMACES* has the potential to transform rural science education initiatives nationwide through providing a low-cost, easy-to-use hardware platform and a curriculum that has been specifically designed to meet the needs of rural classrooms. We will also scale the *LbyM* Networked Improvement Community (NIC) which consists of the professional learning community of ninth-grade teachers, the SSU PD team and

support staff - all networked through the use of Google drive (including all *LbyM* curriculum and teacher-originated materials and assessments); Zoom and in person meetings; and informational listservs. For *STEMACES*, we will add the participating eighth-grade teachers, as well as seek input from STEM+C professionals, advisors, program staff, and community stakeholders.

ABSOLUTE AND COMPETITIVE PREFERENCE PRIORITIES

STEMACES addresses Absolute Priorities 1 and 3 and the competitive preference priority.

Absolute Priority 1 - Moderate Evidence

The SSU team previously implemented a Department of Education Investing In Innovation (i3) project in 2013-2018, which resulted in the first iteration of the *LbyM* curriculum. Subsequent revisions of the curriculum occurred during 2018-2023, supported by EIR. The *LbyM* project has three main components: a) a hands-on, inquiry-based STEM+C three-dimensional science learning curriculum; b) teacher professional development; and c) remote teacher support in rural California high schools. The i3-funded *LbyM* project's impact study showed increased student learning in math and science using a quasi-experimental design that included 150 students (Li et al., 2018). The student population in this study had at least 61% eligibility for Free or Reduced-Price Lunch (FRPL) and the known demographics of the study sample were: 42% White, 41% Hispanic, and 13% English Learners. ***LbyM*'s results are supported by two WWC studies with similar project elements, demographics and settings that provide the required moderate evidence of effectiveness**. Both WWC studies with moderate evidence include two of the three program components described above (a and b) as well as strengthening component c) by adding on-demand support from facilitators or on-site coaching. The two studies are: the AMSTI (Alabama Math, Science, and Technology Initiative) research study (Newman et al., 2012); and the Crafting Engaging Science Environments (CESE) research study (Schneider et al., 2022).

The AMSTI theory of action contains three main program components. The first component "Program materials, technology, and other resources," used a hands-on, inquiry-based, standards-based curriculum that also used technology (albeit loosely defined). There was no set number of units, and fidelity was defined by "full", "partial," or "none" based on what materials were used. Only students who went through two years of the program made gains in science (4th and 5th grades; and 6th and 7th grades). The second component, "Professional Development" included all teachers and support staff in Summer Institutes (SIs). During the SI, the teachers and support staff participated in workshops provided by "master" teachers certified as AMSTI trainers. Finally, the "In-School Supports" component ensured that teachers were fully supported at all times.

The CESE theory of action was similar to AMSTI, containing the same program components, but in high school settings in Michigan and California: a) three 4-6 week Project-Based-Learning (PBL) curriculum units in physics or chemistry that included modeling; b) ongoing teacher professional development and a 3-day institute; and c) ongoing teacher support.

STEMACES will engage with a student population made up of the same demographic (-30% White, -70% other races with greater than 41% Hispanic ethnicity) as the CESE program but in middle schools. We will work in the same middle school setting as AMSTI (which also worked in two elementary grades), but with the population of the CESE program (described above). *STEMACES* meets the Absolute Priority 1 requirements using either study. See the Evidence Form.

Absolute Priority 3 - STEM

As described in the project narrative, STEMACES will be implemented in middle and high schools, and will use inclusive approaches to ensure maximum student and teacher participation in STEM. STEMACES will expand opportunities for high-need students, in particular, youth from rural communities and Hispanic students, both groups being underrepresented in STEM careers.

According to Pew Research Center analysis of federal government data in 2022, Hispanic workers make up 17% of total employment across all occupations, but just 8% of all STEM workers (Funk and Lopez, 2022.) Researchers have found that students in rural classrooms may struggle to receive high-quality STEM instruction due to factors such as lack of technology, insufficient teacher training, and geographic distance from resources (Marksbury 2017). In 2019, 21.1% of rural children in the United States were poor, compared to 16.1 percent of non-rural children (USDA, *Rural America at a Glance*: 2022 Edition). These figures are reflected in our target rural areas in California and Texas, and demonstrated in our list of *STEMACES* Target Schools, Cohort 1, in Appendix F. Our target schools were selected based on their district locale codes: (36 out of 40 or 90% are rural); the percentage of high-need students (at least 50% FRPL); and Hispanic student enrollment (at least 40%) based on data from NCES, for the 2021-22 School Year. **The percentage of high-need students at *STEMACES* target schools ranges from 51% to 95%.**

Poverty and geographical remoteness are only two of the many challenges facing rural education. It is difficult to recruit and retain highly qualified STEM teachers in rural schools (Monk 2007) where advanced courses in STEM are rarely offered (Gibbs 2005). Impoverished rural schools have less access to technology and students learn fewer computer skills (Bouck 2004). *STEMACES* will help address these problems by providing PD that will increase the teachers' Technology, Engineering, and Coding (TEC) skills and by providing a low-cost hardware platform that uses Open Education Resources (OER) software. *STEMACES* will also emphasize sustainability activities that include rural community stakeholders (such as school district personnel, and energy utility or agricultural leaders) in defining innovative field experiences for their students that will build on the acquired STEM skills to address solutions to community problems.

Competitive Preference Priority - Implementers and Partners

The STEMACES team of implementers and partners is specially organized and situated to promote equity in student access to educational resources and opportunities. The lead implementers, SSU and ASU, are HSIs with deep and extensive outreach in communities that serve rural children and students underrepresented in STEM majors and careers. *STEMACES* will leverage this network to expand quality STEM education to these underserved populations. In both California and Texas, Hispanics are now the largest population group (PPIC 2023; Texas Tribune 2023). *STEMACES* school recruitment in California will be bolstered by partners at the Redwood Coast K-16 Collaborative (see letter of commitment), a state-funded effort to increase higher education access for underrepresented students in four northern California rural counties. SSU's commitment to promote equity in educational opportunities is further evidenced by a long history of hosting Department of Education TRIO programs, which focus on college readiness and success for low-income, first-generation students. Of the 2,000 students currently served by Upward Bound and Talent Search at SSU, over 750 attend rural schools. During the past four years, the *LbyM* team has introduced TEC elements of the curriculum to engage approximately 300 TRIO-supported students in coding and electronics activities. *STEMACES* will continue to collaborate and share resources with TRIO staff, while gaining further insight into the needs and strengths of the target communities. TRIO advisors will provide college prep workshops, with a focus on exploration for STEM+C majors (see letter of commitment). Additionally, our organizational membership in the CA Rural Education Network provides access to information and issues unique to rural learning communities.

Furthermore, rural LEAs in both states are significant partners in advocacy, guidance, and dissemination, and will include Education Service Centers (Texas) and County Offices of

Education (California), as well as leadership of past and presently participating schools. The collaboration of implementers and partners will be essential to our plan of operations.

A. SIGNIFICANCE

A.I The National Significance of the Proposed Project

Development of the STEM workforce is essential to innovation and competitiveness (National Science Board, 2015) and early math and science proficiency is foundational to navigating the STEM career pathway. *STEMACES* targets proficiency levels of rural eighth-grade students in science while simultaneously integrating the TEC skill development and problem-solving abilities that are critical to improving the local region's economic development (Gibbs 2005). Moreover, these skills are critical for success of the new rural regional economic development strategies illustrated in the 12-state *Pathways to Prosperity* initiative (Hoffman et al., 2017). Scaling the *STEMACES* model to rural districts nationwide will help close the "digital divide" in TEC learning that significantly disadvantages teachers of rural and low-income students (Kormos and Wisdom 2021). *STEMACES* proposes a solution to this need through a project designed to "promote academic excellence, improve learning conditions, and prepare students for a world where global engagement is critical to our Nation's standing." (Cardona 2023).

A.2 Extent to which Proposed Project Develops a Promising New Strategy

The COVID-19 pandemic accelerated the use of technology in rural and low-income areas, as the greatest use of the internet during the pandemic period was for education (Dahiya et al., 2021). As a result, many rural districts now provide access to a laptop for every student and broadband internet is becoming more common and a national infrastructure priority. However, improved connectivity has not helped to prepare teachers in rural and high-poverty areas to implement TEC in their classrooms (Blanchard et al., 2016). The *STEMACES* scaling model provides the intensive

PD needed to overcome this barrier by training teachers in Computational Thinking (CT) as well as Technology use, Engineering skills, and Coding practices (TEC). CT is used in creating computer models and simulations to better understand and predict phenomena like COVID-19 transmission rates or even changes in the weather or climate. Although the infusion of CT into the science classroom is a promising new strategy for improving learning outcomes in STEM (Li et al., 2020), there is currently no known validated assessment instrument that can measure the use of CT in Technology, Engineering, and Coding-embedded Science Education (which we are calling CT-TEC-Sci). For example, when Tang et al. (2020) reviewed 96 journal articles to analyze CT assessments, they found only 4 of the 96 assessed formal education in middle school and that the assessments were typically designed around programming or computing skills. Few assessments were designed to assess other skills or practices, like computational thinking concepts. The *STEMACES* program strategy, therefore, includes plans to develop a CT-TEC-Sci assessment instrument as part of our efforts to obtain strong evidence for the success of our scaling model.

A.3. Potential to Increase Knowledge and Understanding of Educational Problems

STEMACES will build on strategies for hands-on, inquiry-based learning that began in the 1970s with the development of the Turtle Logo computer language for students (Papert 1972; Papert 1980) and that continues through SSU's *LbyM* curriculum. *LbyM*'s innovative browser-based Web App has been tested by over 900 students in more than 30 science classes over the past 3 years (Cominsky et al., 2023). With a computer that connects to the internet, a Chrome-based browser, and an easily-installed driver for the (Arduino-compatible) microcontroller, anyone can run the freely available, customized, open-source Web App in their classroom or at home, collecting data from a variety of sensors through a simple electronic breadboard and USB cable. As such, it is now possible to inexpensively provide all students with the technology and the

agency to design science experiments in the classroom in a manner similar to that of scientists in the field. These educational innovations will increase knowledge of: how to recruit rural schools and scale TEC curriculum content in rural districts; how to work with the rural communities to increase and sustain TEC within middle school environments; and how to develop units that improve student learning outcomes from two states with quite different science standards.

B. STRATEGY TO SCALE

B.l Strategies that address barriers to scale

The *STEMACES* scaling model includes three components supported by moderate evidence: a STEM curriculum, Professional Development (PD), and Teacher Supports. To these components, *STEMACES* adds innovative OER TEC elements from the *LbyM* STEM+C curriculum, developed by SSU with early-phase funding; TEC elements within teacher PD and student support that led to a scaled Networked Improvement Community (NIC), and the development of the CT-TEC-Sci assessment instrument. The overarching goal of the STEMACES project is to obtain strong evidence of effectiveness that meets WWC standards. Each of these activities has barriers to scaling that require strategies to remove or mitigate, summarized below.

1. Barriers and strategies to scaling the LbyM STEM+C curriculum implementation

Barrier 1.1 - The ninth-grade *LbyM* STEM+C curriculum consists of three skill-building units and three experimental units (Water & Soil, Light & Energy, and Mud-based Fuel Cell) and is designed to completely replace an entire academic year of physical science instruction. Each unit includes 5-8 individual lessons. We have observed that *LbyM* Teachers have struggled to align their classroom activities with the pacing guide, and (particularly during the pandemic) failed to complete all the material as originally planned.

Strategy 1.1 - Curriculum revisions for eighth grade. The eighth-grade *STEMACES* curriculum will be much shorter than the ninth-grade *LbyM* curriculum, consisting of three physical science units, each with approximately 4-6 lessons. This will allow teachers to finish the units with fidelity within an overall curriculum that meets local needs and fulfills additional state-specific standards.

Barrier 1.2 - LbyM was developed using the Next Generation Science Standards (NGSS, NRC 2013) as implemented in California. California and Texas have the two largest K-12 educational systems in the U.S.; however, despite similar demographics, each approaches education from different cultural perspectives. This makes scaling the *STEMACES* learning model to these two states a challenge with national implications. For example, California is one of 20 states that have adopted the NRC Framework for K-12 Science Education (NAP 2012), and NGSS, whereas Texas has developed its own standards (TEKS, 2022).

Strategy 1.2 - Revising the curriculum to meet different science standards in different states. We have analyzed commonalities and differences between the two sets of science standards in California and Texas. There is enough overlap in the standards, that with a creative use of an engaging storyline, common phenomena and driving questions, the planned *STEMACES* curriculum will align with middle-school science standards in both states. We will use and deepen the storyline of the sea turtle for this purpose. For the past two years, we have had great success in engaging *LbyM* students in coding activities through the use of TurtleLogo to model different aspects of the lives of sea turtles in the *LbyM* Unit 1 (http://lbym.org). Turtle Logo (Papert 1970 and 1980) is an introductory computer programming language used to "move" a turtle around to draw pictures. We use it to develop computational thinking concepts and practices. For *STEMACES*, we will expand the sea turtle storyline into Units 2 and 3. Each unit ends with a

performance-based assessment, building on a student's conceptual model as done in Schneider et al. (2022). An overall description of the three units, plans for revisions, and standards alignment is included in Appendix J.

Barrier 1.3 - An additional barrier is the cost for the hardware and software needed to support individual student work at under-resourced rural schools (Kormos and Wisdom 2021).

Strategy 1.3 - Lowering the cost of implementation. STEMACES will utilize several methods to lower the per-student cost of the required materials. The *LbyM* hardware platform components are widely available through many on-line sources, and will be simplified further for *STEMACES* to use objects in a student's environment (e.g., using sunlight instead of lamps).

Increased education-oriented computer access has become increasingly common since 2020 (Vargo et al. 2020). Using Open-Educational Resources (OERs), such as the Chrome browser-based *LbyM* Web App, which can run on any computer, eliminates costs for participating schools that already provide one-to-one computer access. Additional no-cost, research-based OER resources, such as simulations from PhET (http://phet.colorado.edu) and virtual electronic board design with TinkerCAD (http://tinkercad.com) will be utilized both to enhance CT learning outcomes, as well as to support students' conceptual models of challenging physical science concepts (e.g., energy flow and light as a wave).

Teacher professional development model component. Teachers in rural and under-resourced school districts typically have insufficient professional preparation to implement TEC-embedded science curriculum (Blanchard et al., 2016). We have addressed this challenge by the *LbyM* project's yearly PD program which includes multiple one-day academic year PLEs, as well as summer institutes, totaling 80 hours annually. During the past two years, we have evolved our 1-day PLEs during the schoolyear to virtual events.

Over the past 10 years, we have continuously improved our teaching strategies to rigorously follow the best practices recommended by the *LbyM* evaluation team at WestEd. The lessons learned have been codified in the *LbyM* professional development guide, now used prior to each PLE. This guide has three sections: i) creating goals and objectives, ii) determining the main activities to meet the overarching goals, and iii) designing each 1-2 hour professional learning session to meet the objectives of the session. *STEMACES* will continue to use these effective instructional design principles for both online and in-person PLEs.

2. Barriers and strategies to scaling the teacher professional development. The challenge in scaling the PD program is a lack of qualified PD professionals and support staff to meet the needs of the 4-fold increase in teachers across two states.

Strategy 2.1 - Build Capacity Through Partnerships. Additional personnel from WestEd will be trained during Year 1 by *LbyM* PD professionals, in order to build capacity on the *STEMACES* PD team. Additionally, in-person coaches and remote district personnel to support teachers implementing the curriculum will also be invited into the PD program. A cadre of teacher leaders will be formed from those who have successfully taught the *STEMACES* curriculum as part of the treatment cohorts, initially from *LbyM* advocate teachers. The first Summer Institute will bring together six pilot teachers, WestEd and ASU team members, and the *LbyM* advocate master teachers. The *LbyM* PD team will work side-by-side with WestEd PD professionals in a mentor-type learning approach, co-facilitating sessions. The *LbyM* PD guide will be used and modified to account for scaling challenges and to maintain solutions. This NIC-approach enables the WestEd team to learn side-by-side with the other participants while also contributing their expertise in professional learning design and facilitation. Once trained, our WestEd PD personnel will be able

to provide the rural middle-school teachers what they need to implement the *STEMACES* curriculum effectively in years 2-5.

Strategy 2.2 - Enlist Master Teachers as advocates. Approximately six ninth-grade teachers from our early-phase work will support the mid-phase program, while they continue teaching *LbyM* in their ninth-grade classes. Starting in year 2, these master teachers will contribute to the planned Professional Learning Events (PLEs) including teaching strategies, classroom management tips, and content review, advocating for the program within their regions and with rural stakeholders.

3. Barriers and strategies to scaling the Networked Improvement Community (NIC).

Barrier 3.1 - In order to successfully scale the *LbyM* NIC to include as many as 55 teachers in two states, communications pathways must become robust, eliminating barriers to a full support system. For example, teachers occasionally need technical support while classes are in session. They cannot easily attend "drop-in" hours or additional training sessions during the school year. For *LbyM*, this real-time support was arranged by directly calling an SSU IT staff member. This is a practice that will not scale.

Strategy 3.1 - Implement on-line "call center" to support real-time technical issues. We have surveyed technical solutions that will allow teachers to dial a number and reach an on-duty technical support person, enabling real-time technical support that is available during class hours in both California and Texas. In this way, we can multiplex the support staff by including NIC members from WestEd, ASU, and SSU, rather than directing all calls to a specific staff member.

Barrier 3.2 - Both the extant *LbyM* and targeted STEMACES population include an average of 40% Hispanic students: at least 20% of these students are English Learners (EL) or Emergent Bilingual (EB) students (CSBA blog 2017, Texas facts 2019/20). As a result, *LbyM* teachers

frequently reported that EL students would benefit from Spanish translation of the guides, worksheets and readings. Another barrier to success for EL and EB students is presented by differing cultural norms that make science instruction challenging and inequitable (Jones and Burrell 2022).

Strategy 3.2 - Increase equity supports for Spanish-speaking students. To better support Spanish-speaking students, and to increase participation by their teachers in the NIC, we will develop asset-oriented practices including, e.g., the use of translanguage in class and teacher modeling of translanguaging (Suarez 2020). Additionally, master *LbyM* teachers will share their experiences and best practices for working with on-site school translators. We will also create Spanish Language versions of the three-unit curriculum student guide and worksheets, as well as audio files with SSU and ASU bilingual students reading the student guide.

Barrier 3.3 - Approximately half the *LbyM* teachers preferred online access to the curriculum materials, rather than using the printed copies that we have provided. Printing the curriculum materials is very costly, presenting another barrier to scale.

Strategy 3.3 - Increase online availability of TEC student and teacher supports. The *LbyM* WebApp has considerable documentation of available features that will be augmented as the *STEMACES* curriculum develops. We will also investigate the use of online science journals or other tools (e.g., Kami) to record student work (rather than using paper-based worksheets) to improve cost-effectiveness and ease in grading.

4. Barriers to obtaining strong evidence

Barrier 4.1 - During our early-phase work in 2020-2022, we faced significant barriers while implementing our randomized control study with rural schools. Due to the impacts of COVID-19,

we found it very difficult to find new schools willing to undertake a new hands-on, TEC-embedded STEM curriculum.

Strategy 4.1 Recruiting: [redacted], the *STEMACES* recruitment lead, has identified schools that fit our selection criteria and has begun to secure letters of intent to partner. To continue building the cohorts, we have planned recruiting trips around California and Texas to meet schools where they are, literally and figuratively, and have opened conversations with school district administrators, county of education superintendents, and community stakeholders. Where there is interest, members of the *STEMACES* evaluation team will follow up with school leadership, ensuring that they understand what is required for participation in the research study. Finally, the Memorandum of Understanding (MOU) negotiations will take place, including study requirements, annual match required to provide PD and materials, and agreement to support the (very simple) network IT interface

Barrier 4.2 - As previously discussed in A.2., there is no standardized and validated assessment instrument that can measure CT in a TEC-embedded STEM course.

Strategy 4.2 - Develop new CT-TEC-Sci Assessment Instrument and Unit End Assessments. We will develop the CT-TEC-Sci assessment instrument, validate it for use with our program, and disseminate it nationwide after validation. For details of the development plan, see Section D.

B.2. Adequacy of the Management Plan

SSU and ASU have committed facilities, equipment, supplies, and other assets to support the implementation and success of the *STEMACES* program. *STEMACES* will be hosted in the School of Science & Technology in the Division of Academic Affairs at SSU. PI [redacted] will have full authority to commit and expend grant funds on behalf of the program in compliance with

Federal and University policies. An overview of project staff is provided below, with resumes and outline of required qualifications in Appendix B.

In use for the past five years by *LbyM* and other SSU EdEon projects, management of the proposed activities uses the Plan, Do, Study, Act (PDSA) process model (Grunow 2015) to ensure iterative design and improvement over the years of the proposed efforts. Within this framework, the *STEMACES* Leadership Team will consider each problem to solve and develop an initial strategy to address the problem while ensuring that we collect sufficient data to determine the effectiveness of our strategy as it is implemented. In the *Plan* phase, we describe the strategy and make predictions as to what we expect will happen. We then implement the strategy (*Do*) while documenting what happens via formative evaluation by the WestEd Evaluation team *(Study)*. The *STEMACES* Leadership and Evaluation teams then review the results of applying the strategy to the problem and determine what, if any, further modifications are needed (*Act*). If the results of this PDSA cycle are not in accordance with our initial predictions, we repeat the cycle to ensure continuous improvement. The leadership team will meet with external advisors with expertise in different aspects of the proposed scale up program, to gather additional external feedback during the PDSA Study phases.

Tools to support project management in implementing PDSA management include SmartSheets and Excel (schedule and financial), Google Suites (shared communications and documentation), Jira (technical issue tracking), and Zoom (remote communications and PLEs). EdEon employs administrative staff that analyze and reconcile monthly expenses, track schedules, and support PLE logistics and travel. Real-time technical support during class hours will be provided by an on-demand call forwarding service to the scheduled technical support person. Post-award financial activities are supported by the SSU Office of Sponsored Research and Programs.

<u>*Personnel Responsibilities*</u>. SSU and WestEd have partnered on the i3 and EIR-funded early phase grants that created the *LbyM* curriculum for the past 10 years. For this mid-phase proposal, we are partnering with another HSI, Angelo State University in Texas. The *STEMACES* project will be organized into three teams: Leadership, Support, and Evaluation. *STEMACES* and the Leadership Team are led by [redacted], who is the PI, Project Director and manages all SSU personnel employed at EdEon STEM Learning (where she is Associate Director. EdEon is an educational R&D group at SSU directed by Co-PI [redacted].) PI [redacted] will provide project leadership, be responsible for fiscal and ED requirements, oversee the PDSA processes, coordinate with WestEd evaluators, ensure adherence to timelines, budgets, and milestones, ensure the fidelity of the scaling model and, finally, oversee sustainability and dissemination activities. Other members of the Leadership Team include: Prof. [redacted], Co-PI, who is serving as project director for *LbyM* and will continue to direct the curriculum development and implementation; ASU Profs. [redacted] and [redacted], Co-PI, who will oversee the implementation of *STEMACES* by the Texas school partners; and Co-PI [redacted] (WestEd) who will lead the PD efforts to train teachers, support staff, and coaches.

The External Evaluation Team at WestEd is led by [redacted] and [redacted]. [redacted] led the past decade of *LbyM* assessments and will oversee the entire evaluation effort to ensure quality and fidelity. [redacted] will oversee the comprehensive data collection and analysis activities and lead the development of the CT-TEC-Sci measurement instrument. [redacted] has supported *LbyM* evaluation for the past two years. She will act as the Evaluation project manager, coordinating all evaluation activities and providing input to the Leadership Team.

The Support Team at EdEon includes administrative staff (currently [redacted], [redacted] and [redacted]) who will coordinate, purchase, and deliver support and classroom materials, ensure sustainability, handle dissemination and PLE logistics, and support hiring and process payments; graphic artist [redacted], who is responsible for the production and design of all the *STEMACES* curricular and public-facing materials; and IT staff (currently [redacted] and [redacted]) who will maintain the *STEMACES* servers, websites, and *LbyM* Web App. They will coordinate the real-time and Jira-ticket-based support of technical issues. As Logo experts, they will evaluate both infrastructure revisions and the remote help system, as well as participate in the real-time support network. [redacted] will also oversee video production for dissemination and sustainability. Special consultant [redacted] will provide advice and help modify curriculum to guarantee standards alignment for both state systems. Special consultant [redacted], Project Director of the original early-phase i3-funded *LbyM* project, will act as Network and Recruitment Manager, managing partnerships and communications with districts, California County Offices of Education, and Texas ESCs.

Timeline	2024			2025			2026			2027			2028		
	Tri. 1	Tri. 2	Tri. 3	Tri. 1	Tri. 2	Tri. 3	Tri. 1	Tri. 2	Tri. 3	Tri. 1	Tri. 2	Tri. 3	Tri. 1	Tri. 2	Tri. 3
Recruitment	Pilot Cohort		Cohort %			Cohort &			Equity			Sustain			
Scale Model															
Unit 1-3	Revise		Pilot		Revise	Teach			Teach			Teach			
PLEs	Plan	CA TX Pilot	Virtual Pilot		CA TX	Virtual		CA TX	Virtual		CA TX	Virtual		CA TX	Virtual
Teacher Supports		Plan	Pilot		Revise										
Study															
CT in TEC Assessment	Plan	Revise		TX, CA	Revise		TX, CA			TX, CA			TX, CA		
Study	Plan	Pilot Implementation			Implementation Cohort 1			Implementation Cohort 2			Equity Cohort			Sustain Model	
Sustainability & Dissemination				Com-ms	Visits		Com-ms	Visits/ Conf.		Comms	Visits/ Conf.		Papers	Conf.	

Figure 1. Timeline summary of the major efforts during the summers and academic years. The colors represent planning (light blue), pilot testing (pink), implementing (green), equity efforts (dark blue), and sustaining the model (yellow).

An overview of the current timeline is shown in Figure 1. The proposed efforts will span five years: the first year involves revising the *LbyM* curriculum for eighth grade and recruiting pilot

and Cohort 1 schools. As the academic years span two project years, each of the two study implementation cohorts will start with an intensive week-long summer PLE prior to the implementation academic year. Cohort 1 will receive treatment beginning in the summer of year 2; Cohort 2 will begin in the summer of year 3. The CT-TEC-Sci assessment schedule will follow the same schedule as state testing, allowing for a comparison of results as part of our study (see Section D). Sustainability and dissemination activities begin in year 2, as relationship building and support in rural areas takes years of building trust. We anticipate some control schools will want to implement the *STEMACES* curriculum beginning in year 3. These control schools can choose either to move directly to implementation or to participate in the school-level randomization to become part of the Cohort 2 study. Following each of the two study years, the control schools will be offered the opportunity to implement the *STEMACES* curriculum. Based on historical engagement with rural and Hispanic-serving schools, we anticipate most of the schools we work with will want to continue to implement the course and remain in the NIC while continuing to increase their knowledge and skills in TEC. A more detailed, monthly timeline of activities can be found in Appendix J.

B.3. Applicant's Capacity to Bring the Proposed Project to Scale on a Regional Level

For almost a decade, SSU has worked with rural communities across the state to develop and test its *LbyM* curriculum. We refined our recruitment strategy (4.1) amid the pandemic, successfully adding two rural schools in Southern California, despite the difficulties posed by year-long school closures. The switch to remote Professional Learning Events (PLEs) and the development of the Web App give us confidence in our ability to scale with fidelity in rural regions. Our partnership with [redacted] and his team at ASU will ensure that we will scale the *STEMACES* program with fidelity in rural schools within west-central Texas regions 15 and 18.

ASU is a dynamic university located in San Angelo, a small west Texas city of 100,000, and is adjacent to two rural school districts. A long-time HSI, ASU has been awarded more than $8 million in HSI grants.

The *STEMACES* team at SSU will work directly with LEAs in California and, through ASU, with LEAs in Texas. Whereas California rural school networking involves partnerships with County Offices of Education (COEs), Texas outreach will rely heavily on Educational Services Centers (ESCs) for professional development and assistance in improving student outcomes. Both the ESC for Region 15 and ASU are located in San Angelo: this region covers a large portion of west-central Texas, where most of our Texas target schools are located. Over the last two decades and with the help of the Region 15 ESC, ASU's Department of Physics & Geosciences has run successful professional development workshops for teachers, and teachers from rural districts near San Angelo often travel to campus to use lab equipment and perform laboratory activities with the aid of ASU faculty. Institutional and partner support are documented in Appendix C.

B.4. Sustainability and Dissemination for Further Development and Replication

Sustainability. We aim to support schools in authentically adapting the *STEMACES* model for their local education needs while maximizing student learning outcomes. To do this, we will meet with local stakeholders (education professionals, superintendents, school administration, teachers, and IT support staff) to offer ideas for a STEM+C education strategic plan that sustains and builds on *STEMACES*. By lowering the costs of student materials and expanding the NIC, districts can readily take on the program in a way that best suits their needs. One important part of this decentralization of the program will be to encourage *STEMACES*-trained teachers to become TEC teacher leaders, conducting additional TEC trainings throughout the district, and growing the NIC to include these new voices and expertise.

Dissemination. We will share promising implementation and TEC practices learned through *STEMACES* with other PD professionals and teachers at annual conferences organized by the California Association of Science Educators, Science Teachers Association of Texas, and the National Rural Educators Association. Scaling and evaluation of promising practices, outcomes, and OER tools, such as the CT-TEC-Sci assessment, will be shared on WWC via research journal articles and at conferences such as AERA (American Educational Research Association) and NARST (National Association for Research in Science Teaching). We will use the *STEMACES* website and social media to inform non-profits and other school administrators and teachers of our OER tools and professional development opportunities. The required dissemination plan will be developed in year 2. We also expect other educators to use our CT-TEC-Sci assessment tool once it has been validated. The creation of this tool will help to increase educators' ability to assess CT within the context of other TEC-enhanced science curricula.

B.5. The potential for STEMACES resources to be used effectively in other settings

Open Educational Resources: OERs such as the *LbyM* Web App, as well as the related TEC skills needed to build and control circuits, are ideally suited to be used in a variety of other settings beyond middle and high schools. For example, the three *LbyM* skill-building units, which serve as the starting point for *STEMACE*S curriculum revisions, have positively impacted under-represented undergraduate students at SSU and Howard University (an historically Black university) who work on SSU's NASA-funded CubeSat (small satellite) project. The undergrads work through *LbyM* lessons introducing coding in Logo, controlling electronic circuits with microprocessors through a computer interface, and gathering sensor data in the form of packets for data analysis. The *LbyM* curriculum thereby establishes a common vocabulary for computer science, engineering, and physics undergraduates to use when working together on the CubeSat.

It also provides students with a conceptual framework for how science is truly done in Earth and Space science research. Not only does our curriculum cater to the naturally diverse skill levels of our students, it also fosters interest in and the skills necessary for modern workforce needs. Many of the skills we teach, for example, increase exposure to computer programming, troubleshooting, and design elements of modern electronics.

Material Considerations. Lowering the cost to scale will encourage the adoption of *STEMACES* in other settings. We will develop a cost model to minimize prices for the basic *STEMACES* kits that provides individual students with access to the required technology and sensors. We anticipate being able to share a shopping list for kits that should total less than $30 per student. Other examples of cost-saving strategies consist of students pairing up, working in teams, or using easily accessible stations for larger groups of students. Scientific simulations are part of the science standards at the high school level and are an important part of scientific research.

C. QUALITY OF THE PROJECT DESIGN

C.1. Conceptual Framework Underlying the Proposed Research

The *STEMACES* Theory of Action, shown in Figure 2, incorporates three project components within a coherent system (Teacher PD, revised STEM+C curriculum, supports for teachers and students). Each component combines an element with moderate evidence from the studies listed in Absolute Priority 1 with promising innovations from our early-phase work. These augmented components

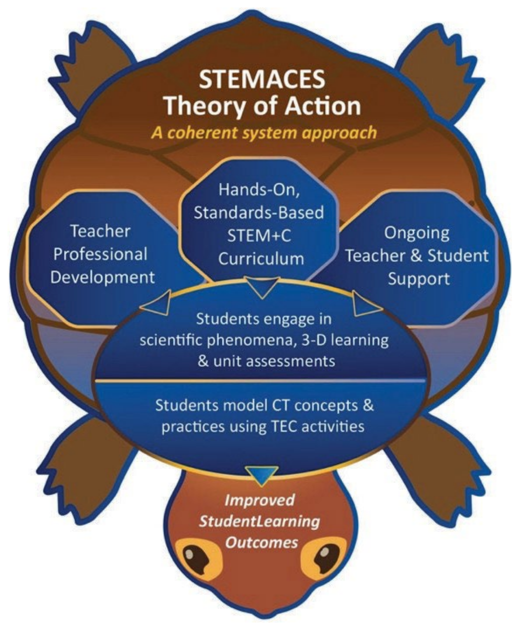

Figure 2. STEMACES Theory of Action. The turtle represents the origins of TEC-related education using a mechanical turtle (Papert 1970.)

support student engagement through posing questions to understand scientific phenomena within a three-dimensional learning framework. Additionally, engagement in trans-disciplinary CT concepts and practices and TEC activities will lead to improved student learning outcomes that are measured by unit-end assessments and standardized state tests. The Logic Model in Appendix G and Fidelity Matrix in Appendix J describe how specific inputs, output components, and output participation lead to desirable short, medium, and long outcomes.

C.2. Goals, Objectives, and Outcomes Are Specified and Measurable

Figure 3 summarizes our goals, project objectives, outcomes and performance measures. The two main goals are to scale the *STEMACES* model with fidelity and to obtain strong evidence of improvement that meets WWC standards. For information about the timing of each measure, please see the Timeline in Section B.2, the Evaluation Section D, and the attached Government Performance and Results Act (GPRA) Form.

C.3. Design of the Proposed Project Addresses the Needs of the Target Population

Throughout this proposal, we have demonstrated the national need for improved science outcomes for rural students; for TEC skills and CT thinking in rural high-need populations of both teachers and students; for increased connectivity with local stakeholders to develop sustainable STEM+C supports; and for developing the CT-TEC-Sci assessment instrument. These four major needs are all addressed by the Logic Model shown in Appendix G.

D. PROJECT EVALUATION

D.1. Methods Designed to Meet WWC Standards Without Reservations

WestEd will conduct an independent evaluation to address seven research questions (RQs) about the impact of *STEMACES* on students' science learning and teachers' competencies in science teaching, shown in Figure 4. We propose to use a blocked cluster randomized controlled

Goals, Objectives, Outcomes & Performance Measures

Project Objectives	Outcomes	Performance Measures
***Goal 1:** The STEMACES model is scaled with fidelity, overcoming barriers to scale.*		
1.1 Revise the LbyM curriculum to scale to middle school.	- LbyM curriculum is revised for eighth grade - Curriculum includes required elements to reduce barriers to scale and improve student math and science learning outcomes. - Curriculum pilot-tested & implemented with fidelity	- Three STEM+C units reviewed for completeness - Teacher logs - Teacher Surveys
1.2 Build capacity in partners to scale the LbyM PD Program.	- New professional **PD** providers & coaches (Wested personnel, master teachers & coaches) are trained - Master-teacher advocates from LbyM are enlisted - Scaled PD model is co-designed & implemented	- Attendance logs - Online PLE documents - PD provider surveys - Teacher surveys - Pre & post teacher competency surveys
1.3 Expand teacher and student supports to scale the Networked Improvement Community.	- PD providers, coaches & master teachers are added to LbyM listserv & appropriate Google-Drive folders - Automatic call routing to support-providers is added for on-demand help - TEC student online supports availability increased - Asset-based practices to support emergent-bilingual students are added	- Listserv use - Teacher-supported call logs - Teacher surveys - Teacher logs - Call center logs - Spanish translations - Spanish videos
***Goal 2:** The STEMACES Model is evaluated to meet Tier 1 Strong Evidence for WWC*		
2.1 Successfully recruit & implement the study with rural schools that fit our selection criteria	- In-person meetings held with rural school administrators & teachers - MOUs are implemented to ensure fidelity & support from school administration - Teachers participate in PD & teach three curriculum units - Students engage with all three curriculum units	- Meeting agendas - Number of MOUs in place - Teacher logs and surveys - PLE documents - High-need student class enrollment numbers - Overall student class enrollment numbers - Student work on end-of-unit assessments
2.2 Assess the ***STEMACES*** Program on student science learning.	- Student eighth grade science results are compared to seventh grade math and ELA baseline data - Students take the CT-TEC-Sci assessment - Students take the end-of-unit assessments	- Students' seventh-grade math & ELA scores - Students' eighth-grade math & science state test scores - Students' CT-TEC-Sci assessment scores
2.3 Collect cost data & analyze cost-effectiveness	- Determine cost model - Analyze cost per student	- Cost model memos - Cost per student

Figure 3. Goals, Objectives, Outcomes, and Measures to ensure success of STEMACES

Research questions (RQs)	Data source and collection timeline	Performance Measures
RQ1: Does *STEMACES* improve science learning for 8th grade students?	**- Cohort 1: 2025-2026** Both pretest (7th grade math achievement) and outcome (8th grade science achievement) will be provided by the school districts in spring 2026; project-developed assessment will be administered to students at the end of spring 2026 **- Cohort 2: 2026-2027** Both pretest (7th grade math achievement) and outcome (8th grade science achievement) will be provided by the school districts in spring 2027; project-developed assessment will be administered to students at the end of spring 2027	Two-level hierarchical linear modeling (HLM), students nested within schools, based on the combined Cohort 1 and Cohort 2 data
RQ2: Does *STEMACES* improve teacher's competencies in science teaching?	**Teacher competency survey** - Cohort 1: 2025-2026 - Pretest: fall 2025 - Posttest: spring 2026 - Cohort 2: 2026-2027 - Pretest: fall- 2026 - Posttest: spring 2027	Regression analysis, combined Cohort 1 and Cohort 2 data
RQ3: To what extent is the impact of *STEMACES* on student science learning moderated by student demographics and background (such as ethnicity and income status) and by level of implementation fidelity?	- Student demographics and background will be based on the district educational records, provided by the school districts during the study year for each cohort - Implementation data will be collected by the study team for each cohort	Two-level hierarchical linear modeling (HLM), students nested within schools, adding an interaction term (treatment status by moderator) to the impact model similar to the one for RQ1
RQ4: To what extent is the impact of *STEMACES* on student science learning mediated by teacher's competencies in science teaching?	Student outcomes: see RQ1 Mediator: see RQ2	Structural equation modeling (SEM)
RQ5: To what extent is *STEMACES* and its scaling strategy implemented with fidelity?	- Teacher log: collected every other month, during the study year for each cohort - Teacher interview/focus group: collected twice during the study year, first at the end of fall semester, second at the end of spring semester, for each cohort	Descriptive analysis and qualitative data analysis
RQ6: What are the factors that facilitate or hinder the implementation of *STEMACES* with fidelity?	See RQ5	See RQ5
RQ7: What are the monetary costs of implementing *STEMACES* in schools and the cost-effectiveness of *STEMACES* for student outcomes?	Program cost records	Cost analysis at the end of 2027

Figure 4. STEMACES Research Questions

trial (RCT) to answer these research questions. This design allows us to collect valid and reliable data so that the impact findings will likely meet the What Works Clearing house (WWC) standards without reservations (the highest rating representing strong evidence).

Evaluation design. The evaluation will include one cohort for the pilot study and two cohorts for the impact study. Each cohort will consist of eighth-grade students in science classes. We plan to recruit up to 6 schools for the pilot study in 2024-25. The pilot study aims to try out the treatment to gather information to refine *STEMACES* for at-scale implementation for the impact study.

Two cohorts of students from 80 schools in California and Texas will be recruited for the impact study, first in 2025-26 (40 schools) and second in 2026-27 (40 schools). Within each cohort, schools will be randomly assigned to either treatment or control groups within states, with teachers and students in the same schools receiving the same experimental assignment. Using school as a unit of random assignment can minimize threats to internal validity, such as contamination commonly found in studies where randomization occurs within schools. The total of 80 schools in the impact sample will provide sufficient statistical power to detect the impact of *STEMACES* on student outcomes (our primary interest). The power analysis is described in more detail below.

Schools (K-8 or middle school) serving at least 50% of students receiving free or reduced lunch and a high percentage of Hispanic students (averaging around 40%) will be eligible to participate in the study. Teachers in the treatment schools will receive professional development on using *STEMACES* and incorporate the three units of *STEMACES* into their existing science curricula. On the other hand, teachers in control schools will implement their existing science curriculum ("business as usual"). They will be offered the option to receive delayed treatment at a later date.

Sample size and power estimates. For the impact study, we plan to recruit a total of 80 schools altogether over two consecutive years. We conservatively estimate one teacher with 20 students in the science class per treatment or control school. Assuming: (1) alpha=0.05, (2) a two-tailed test, (3) power=0.8, (4) the intraclass correlation coefficient (ICC) is 0.15, (5) the proportion of variance explained by covariates at each level is 0.5, (6) the number of blocks is 10, and (7) fixed block effects, the estimated minimum detectable effect size (MDES) based on the *PowerUp!* tool (Dong & Maynard, 2013) is 0.20 for the proposed two-level HLM analysis where students are nested within schools. The MDES will be 0.23 if the number of schools decreases to 60, holding others constant.

For the teacher outcome, assuming that there is only one teacher per school and the proportion of variance explained by covariates is 0.6, with the same alpha level, two-tailed test, and the same power as for the student outcomes, the estimated MDES is 0.4. The MDES is 0.47 if the number of teachers/schools decreases to 60.

Data collection & measures. The evaluation team will collect various types of data based on the scheduled timeline in Figure 1 and detailed in in Appendix J. Student background and prior achievement data will be gathered from district/school administration records. Because there is no state science assessment in seventh grade, we will collect the math achievement data instead. For student outcomes, we will use the state's eighth-grade science test as the primary outcome. The state test is considered to be valid and reliable by the WWC. We will collect the science scores in the spring of each study year from the participating schools or districts.

We also plan to use the project-developed assessment, the generalized Computational Thinking in Technology, Engineering, and Coding-embedded Science education (CT-TEC Sci) assessment, as the secondary/exploratory outcome. The instrument will be developed during the pilot year and

validated with empirical data in the Cohort 1 study year. It will be used in the impact analysis in the Cohort 2 study year. The final version of CT-TEC Sci will consist of 40 multiple true-false (MTF) questions assessing students' understanding of Data Practices, Modeling & Simulation Practices, Computational Problem-Solving Practices, and Systems Thinking Practices.

For teacher outcomes, we will assess teachers' competencies in science teaching through the Teacher Competency Survey (TCS). The survey was developed for the *LbyM* i3-funded project by WestEd and Sonoma State University in 2014. It includes two subscales with a total of 34 items. The first subscale is a 4-point Likert-type scale ("1" = need to learn this, "4" = I can teach other educators) that assesses teacher competencies in supporting students' critical thinking skills (12 items, Cronbach's alpha=0.92) (e.g., I design learning activities that require students to apply existing knowledge to generate new ideas, products, or processes). The second subscale is a 5-point Likert-type scale ("1" = strongly disagree, "5" = strongly agree) that measures teacher technology competencies (22 items, Cronbach's alpha=0.93) (e.g., I know how to solve my own hardware problems). Each subscale will be analyzed separately. The pretest version of TCS will include items collecting teacher demographic data, such as gender, ethnicity, academic and technology background, and teaching experience.

Implementation data will be gathered through teacher logs and teacher interviews/focus groups. In the teacher log, we will ask teachers how they implement *STEMACES*, how it works for students, their challenges in delivering the curriculum, and how students interact with them when learning science concepts and skills through various tasks. We also plan to conduct teacher interviews or focus groups to solicit more in-depth information about delivering science content with *STEMACES* and the factors that hinder or facilitate student learning. An end-of-unit assessment will be administered to students when they complete each unit. These data will be used

for teachers to monitor their student's progress over time and allow them to identify concepts or practices difficult for students to understand. School background information will be obtained from the Common Core of Data (CCD) at NCES.

Analysis methods. We will use the most appropriate analytic approach to address each research question. For RQ1 and RQ3 related to student outcomes, a two-level HLM that takes into account the nested structure of data (students are nested within schools) based on the intent-to-treat sample will be used. To improve the precision of the treatment impact, we will include the blocking variable (treated as a fixed effect) and prior year of math achievement as well as some student-level and school-level characteristics (such as gender, ethnicity, income level) as covariates in the impact model. For the moderator/subgroup analysis, an interaction term of treatment indicator by subgroup will be added to the impact model. We plan to conduct the subgroup analysis by gender, ethnicity (such as Hispanic versus non-Hispanic, White versus non-White), income level (if available), and prior achievement level (low versus high). The state's prior math achievement scores and science scores (the outcome variable) will be converted to z scores based on each state's means and standard deviations. It is a common practice to conduct analyses when combining assessment data from different states is needed.

For teacher outcomes (RQ2), a single-level regression model will be used. Similar to the impact model for student outcomes, the blocking variables and some teacher-level characteristics will be included as covariates in the model to improve the precision of the impact estimate.

For the mediator analysis (RQ4), a two-level structural equation modeling (SEM) will be used to examine how teachers' competencies in science teaching may affect students' science learning. Some teachers' classroom practices (such as quality and quantitative use of problem-solving approaches in demonstrating science concepts) will also be considered potential mediators.

To study the implementation data, we will use descriptive and qualitative data analysis to capture how each component is implemented and what factors may hinder or facilitate the implementation. We will summarize the data according to the implementation fidelity matrix (Appendix J) to determine the level of fidelity (such as low versus high). This information can be used to examine if there would be any differences between students under high level of fidelity versus those under low level of fidelity (part of RQ3).

We will conduct a cost analysis using the ingredients method (Levin, McEwan, Belfield, Bowden, & Shand, 2018) to estimate the cost of the resources required to implement *STEMACES* in 8th-grade classrooms. *CostOut* toolkit (Hollands, et. al., 2015) will be used for this analysis.

D.2. Generation of Guidance About Effective Strategies Suitable for Replication

Standards for Excellence in Education Research (SEER; Institute of Education Sciences, 2022) promote the accumulation of scientific knowledge through transformational research that supports replication. The evaluation team will demonstrate integrity and transparency by pre-registering evaluation design and analysis methods. At the end of the study, we will dedicate resources and efforts to share with the public the final deidentified analytic data, data codebooks, and the sample codes generated to run HLM and SEM for the analyses. The evaluation team has previously shared such data through the Inter-university Consortium for Political and Social Research (ICPSR). ICPSR provides leadership and training in data access, curation, and analysis methods for the social science research community. Future researchers can reproduce our results and conduct secondary analyses using our shared data sets. Provided detailed information on the context and components of *STEMACES*, the proposed study will allow others to build on our work.

The evaluation's findings addressing those research questions will demonstrate what and how *STEMACES* works for high-need eighth-grade students from 80 schools with a high concentration

of Hispanic students. We will provide detailed background information (such as school location, student enrollment data, family income level, and student ethnic distribution) about those schools that will allow for replication. We will document, summarize, and report the implementation data collected through teacher logs and interviews/focus groups to share information about how teachers implement the treatment in their classrooms and in what ways it improves student science learning, as well as what factors prevent them from effectively carrying out particular treatment component(s). We will conduct the proposed impact, moderator, and mediator analyses and share the findings with a broad audience so that the districts or schools can consider using *STEMACES* in their schools. Findings of cost analysis can determine if *STEMACES* is a cost-effective investment, adding information to the districts and schools to consider when selecting a science treatment program for their middle school students.

D.3. Components, Mediators, and Outcomes and Measurable Threshold

As depicted in the logic model (Appendix G) and described in the narrative, the *STEMACES* scaling model will implement three components: a STEM curriculum, Professional Development (PD), and Teacher and Student Support. To these model components, the program team will add innovative Technology, Engineering, and Coding (TEC) elements from SSU's ninth-grade Learning by Making (LbyM) curriculum that includes TEC elements within teacher PD and student support and develop and validate the CT-TEC Sci assessment for evaluating TEC-embedded STEM curricula. The three model elements and the proposed innovations comprise the scaling model. The main goals of STEMACES are to increase teacher instructional competence and self-efficacy (a key mediator) through training in the use of TEC tools and CT activities, thereby improving student academic achievement in science.

With inputs from the management team and based on the previous *LbyM* work, we laid out a plan to measure implementation fidelity with acceptable thresholds (Appendix J.) We will finalize it during the pilot study and, if needed, in the Cohort 1 study.

D.4. Providing Performance Feedback Towards Achieving Outcomes

For the impact study, we plan to collect teacher logs every other month during the study. Each time we will ask teachers how they implement *STEMACES*, how it works for students, their challenges in delivering the curriculum, and how students interact with them when learning science concepts and skills through various tasks. We also plan to conduct teacher interviews or focus groups twice a year, first at the end of the fall semester and second at the end of the spring semester, to solicit more in-depth information about delivering science content with *STEMACES* and the factors that hinder or facilitate student learning.

Information collected, either from the teacher log or the teacher interview/focus group, will be analyzed promptly. The evaluation team will share the findings with the management team so that they know how to assist teachers in carrying out the curriculum to promote student learning. Data collected from the each of the three end-of-unit assessments will help teachers monitor their student's progress over time and identify concepts or practices difficult for students to understand and learn. We also plan to conduct an exploratory impact analysis at the end of the Cohort 1 study. It will provide us with the preliminary information on the effectiveness of *STEMACES* on student learning and teachers' competencies in science teaching. The final impact analysis will be based on Cohort 1 and Cohort 2 combined data.

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