CFDA #: 84.411C

2013 i3 Grant Application

Grant Proposal: Engineering STEM Identity (ESI)

Maricopa County Education Service Agency
4041 N. Central Avenue, Suite 1200
Phoenix, Arizona 85012

Submission Date: August 16, 2013
Grant Proposal Due: August 16, 2013 @ 4:30:00 PM (Eastern Daylight Time)

MCESA
Maricopa County Education Service Agency

ESI Table of Contents

A. Significance 1

Priorities Addressed 1

A1. The National Challenge and Novel Approach 1

A2. Contribution to Development and Advancement of Theory 3

A3. Better Student Outcomes through Engineering STEM Identity (ESI) 6

B. Quality of Project Design 7

B1. Addressing Absolute Priority 3 and Subpart (a) 7

B2. Clarity and Coherence of Project Goals 8

Engineering STEM Identity (ESI) 8

B3. Clarity and Coherence of Project Activities 9

Redesigning STEM Course Content to Engage Students and Increase Achievement (Goal 1) ... 9

Redesigning Instructional Practices to Improve STEM Education (Goal 2) 11

C. Quality of Management Plan 13

C1. Responsibilities, Timeline, and Milestones 13

C2. Commitment of Key Partners 16

C3. Project Feedback and Improvement 17

D. Personnel 17

Responsibilities of Key Personnel 18

E. Quality of Project Evaluation 20

E1. Project Evaluation Design and Questions to Determine Impact and Fidelity 20

E2. Evaluation Plan with Sample Size, Effect Size, and Analytic Approach 21

E3. Outcomes of the Project and Implementation Study: Implementation Study 24

A. Significance

Priorities Addressed

Maricopa County Education Service Agency (MCESA) is responding to *Absolute Priority 3 – Improving Science, Technology, Engineering, and Math (STEM) Education. (a) Redesigning STEM course content and instructional practices to engage students and increase student achievement:* The proposed project develops a novel approach to address the national STEM professional shortage. The project will use strong theory based approaches to build upon previous efforts for supporting 6th through 8th grade students and teachers. The project will create a prototypical process for developing student STEM Identity that will add to the development and advancement of theory, knowledge, and practices for K-12 STEM education.

A1. The National Challenge and Novel Approach

Nationally, engineering corporations and technology-dependent industries face a future shortage of highly skilled employees, and colleges and universities are unable to meet the increased demand (NAE, 2013). Without research-based intervention, this urgent need will not be fulfilled. For decades, researchers in science and engineering education have been working toward increasing student persistence and likelihood to choose STEM careers. Arizona's efforts to prepare its students in math and science continue to fall short and contribute to the greater national STEM professional crisis. According to the 2013 Arizona's Instrument to Measure Standards (AIMS) assessment, 43% of Arizona's 8th graders did not meet the Science State Standard, and 39% did not meet the Mathematics State Standard. The National Assessment of Educational Progress (NAEP) reports that Arizona consistently ranks below the national average in math and science. This trend suggests that the current education systems in place for developing additional STEM professionals need to be reengineered to promote student engagement, achievement, and persistence in STEM fields.

Student achievement alone does not predict student persistence in STEM. When students do not persist in STEM, they do not continue on to become STEM professionals. This national phenomenon is called the leaky pipeline and is the underlying premise in a shortage of STEM professionals (NAE, 2013). In an attempt to understand what might be the underlying cause of STEM persistence, researchers have shifted to examining student STEM identity. Student desire to pursue science careers is dependent on whether they find scientific practice to be consistent with their identity (Archer et al., 2012). In order to ensure student identities are aligned with STEM fields, explicit attention must be paid to the development of their identities. The approach proposed will redesign courses building on the cross-cutting concepts in the Next Generation Science Standards (NGSS) and past curricular attempts to address isolated components that build STEM identity.

The pipeline of students prepared for STEM professions is also affected by a shortage of qualified math and science teachers with content and pedagogy expertise to effectively teach those subjects, especially in poverty or rural areas. A cause of the shortage of qualified K-12 science and math teachers is the reported decline in content knowledge preparation (Moin, et al., 2005). Nearly, 32% of science and math teachers report majoring in neither math nor science (USDOE, 2010). This national trend is particularly prevalent in Arizona in which almost 80% of math and science teachers do not hold a state teaching certificate in either math or science (Gau, Palmer, Melnick, & Hefferon, 2003). Rural communities often experience greater difficulty filling teaching positions, in specialized content areas such as math, science, and technology (Monk, 2007). These STEM teacher shortages frequently result in unqualified teachers filling positions, which negatively impacts student achievement (National Commission on Teaching and America's Future, 2002). These findings are of great concern due to the correlation between teacher pedagogical content knowledge and improved student achievement (Ball, Hill, & Bass, 2005; Darling-Hammond, 2000; Shulman, 1986, 1987; Wößmann, 2003). The proposed

approach will also support teachers in effectively implementing reengineered course content with professional growth that includes pedagogical content knowledge.

A2. Contribution to Development and Advancement of Theory

In response to the literature and Absolute Priority 3, Engineering STEM Identity (ESI) targets middle school students to maximize student persistence in STEM. Emphasizing STEM identity increases the amount of students entering and persisting in the pipeline. Identity in the context of STEM has been defined inconsistently throughout the research as: an individual's understanding of her or himself as an individual STEM entity (Herrera, Hurtado, Garcia, & Gasiewski, 2012); the interactions between an individual and the STEM community (Carlone & Johnson, 2007); an understanding of internalized social roles (Archer et al., 2012; Hererra et al., 2012); the interface between student academic performance, institutional connectedness, gender role, and mentors in engineering (Capobianco, French, & Diefes-Duz, 2012); and the interaction between gender norms and social perception of science (Archer, et al., 2012). In order to understand identity further, ESI employs the theoretical lens of self-concept from the national and international educational psychology literature which will support the development and advancement of identity theory and knowledge in the STEM Education field.

Self-concept describes the perception of oneself based on experience, environmental feedback, and recognition (Marsh, 1990; Marsh, Craven, & Debus, 1998; Marsh et al., 2005). The portion of self-concept aligned to success in learning is called academic self-concept. In students of grades 5-10, academic self-concept is further divided into math and verbal academic self-concept (Shalveslson & Marsh, 1986; Marsh, 1990). However, when this distinction was made, the subjects contributing to math academic self-concept were math, physical sciences, life science, and business (Marsh, 1990). At the time of study, engineering and technology were not considered core subjects and were not included in the model. With this broad definition of math academic self-concept, we

argue that it addresses STEM academic subjects. For the purpose of this study we, more appropriately, will refer to math academic self-concept as STEM identity.

STEM identity begins to develop as young as age five; though students up to age eight tend to consistently have inflated STEM identities that results from an optimistic bias (Marsh et al., 1998). STEM identity then decreases through high school then increases into adulthood if a STEM interest is pursued (Marsh et al., 1998). Student STEM identity at age 14 predicts the likelihood of persistence in STEM coursework through college (Archer et al., 2012). This finding supports providing opportunities to maximize the development of STEM identity for middle school-aged students. Differences in male and female achievement and attitude in STEM subjects are prevalent starting at 8th grade (NSF, 2006; Post-Kammer & Smith, 1985). While the focus of this project is not gender differences in STEM performance and success, we must consider the discrepancies between female and male STEM participation in order to establish a successful approach. In doing so, the project may add to the development of theory and practice to support females entering and persisting through the STEM pipeline. Barriers to females persisting in STEM are similar to those faced by other underrepresented populations: difficulty relating to STEM careers (Carlone & Johnson, 2007; Archer et al., 2012), lack of alignment between life goals and STEM (Kozoll & Osborne, 2004; Archer et al., 2012); and altered expectations that align to cultural norms for success (Choo & Ferree, 2010; Archer et al., 2012). Additionally, there is a progressive decrease in participation of Hispanic students in STEM as they move through the pipeline (Chapa & De la Rosa, 2006). Because MCESA serves female and Hispanic populations, these unique challenges may provide insights on underrepresented populations for activities that might develop STEM identity.

Factors contributing to the STEM Identity development are access to **role models** (Shapcott, Nelson, & Husman, 2012; Archer et al., 2012; Capobianco et al., 2012), **academic success** (Marsh, Trautwein, Ludtke, Köller, & Baumert, 2005; Capobianco et al., 2012), **sense of institutional**

belonging (Capobianco et al., 2012; Herrera et al., 2012), **gender expectations** (Archer et al., 2012; Herrera et al., 2012; Fouad et al. 2010; Capobianco, 2012), **recognition** (Carlone & Johnson, 2007; Herrera et al., 2012), **curricular relevance** (Tucker-Raymond & Pappas, 2007), and **task oriented self-efficacy** (Shapcott et al., 2012).

Figure 1: Theoretical Framework

Together, these factors form the left half of the theoretical framework and guide the goals and activities of the project (Figure 1). The current literature and practice have focused on a limited number of these STEM identity factors; however, very few have examined STEM identity holistically and designed courses to include all factors to support student success.

The right side of the theoretical framework (Figure 1) addresses the need to support teachers in implementing course content effectively. An important component for supporting teacher professional growth is developing teacher pedagogical content knowledge (PCK), or a teacher's ability to understand the pedagogy related to specific content. Professional development that addresses **declarative PCK** (knowing *what*)**, procedural PCK** (knowing *how*)**, conditional PCK** (knowing *when* and *why)***,* **self-regulation, and self-efficacy in inquiry** best supports science teacher professional growth (Michalsky, 2012). Upon reviewing current theory, knowledge, and national practices, ESI will answer the following questions to advance a more complete theory for STEM

course and instructional practice redesign: How does a prototypical process, ESI, increase student achievement and engagement by developing STEM identity?

A3. Better Student Outcomes through Engineering STEM Identity (ESI)

An approach that maximizes a comprehensive inclusion of multiple factors to facilitate the development of STEM identity will increase student achievement as measured by standardized test scores (Marsh et al., 2005).This approach substantially produces better outcomes by examining holistic STEM identity rather than previous efforts to solve the national STEM professional shortage which have had isolated emphasis on constructs such as interest, achievement, motivation, or self-efficacy. ESI will provide a replicable prototype for redesigning STEM course content in middle school that includes a unique Modeling Curriculum. In partnership with the American Modeling Teachers Association, Modeling curriculum aligned to Next Generation Science Standards (NGSS) will be implemented for sixth, seventh, and eighth grade emphasizing the disciplinary core ideas, crosscutting concepts, and science and engineering practices as defined by NGSS.

Integration through Modeling Instruction supports achievement gains in both math and science (Utley, Moseley, & Bryant, 2005). Additionally, when taught by teachers with expertise in Modeling Instruction, student achievement gains were doubled compared to students taught by traditional instructors (Jackson, Dukerich, & Hestenes, 2008). After two years, teachers without science degrees who participated in Modeling Workshops produced student gains equivalent to teachers with science degrees who did not participate (Hestneses, 2000).

By creating a prototypical process for developing student STEM identity and a model for disseminating professional development to remote areas, ESI will test a theory based approach to promoting persistence in STEM to increase student achievement. The two goals of this project are to (1) increase student achievement and engagement by redesigning course content to develop STEM identity and (2) increase teacher effectiveness and confidence in implementing redesigned course

content and instructional practices. ESI will develop STEM identity in 2300 students across three years, supporting the persistence of students in the STEM pipeline. Additionally, ESI provides crucial professional development to 32 teachers such that they can continue to develop student STEM identity past the life of the project and contributing to their students' STEM persistence.

B. Quality of Project Design

B1. Addressing Absolute Priority 3 and Subpart (a)

Absolute Priority 3 – Improving Science, Technology, Engineering, and Math (STEM) Education. (a) Redesigning STEM course content and instructional practices to engage students and increase student achievement. The proposed project improves STEM education to address the national STEM professional shortage. The project will use strong theory based approaches to build upon previous efforts for supporting middle school students and teachers. The project goals and objectives address Absolute Priority 3 and its subpart.

Table 1: Project Goals and Objectives
Goal 1. By 2016, increase 2300 students' achievement and engagement by redesigning course content to develop student STEM identity. • Objective 1.1. Increase student achievement in STEM disciplines by 10% on a state science and math assessment and a performance based assessment. • Objective 1.2. Increase student engagement in STEM subject areas by 20% as measured by research validated student survey.
Goal 2. By 2016, increase 32 teachers' effectiveness and confidence in implementing redesigned course content and instructional practices. • Objective 2.1. Increase teacher STEM pedagogical content knowledge by 34% or one Standard Deviation as measured by LOI observation instrument and BECI content assessment. • Objective 2.2. Increase teacher confidence in STEM education by 20% gain as measured by teacher survey.

ESI is a model focused on developing student STEM identity to increase achievement and engagement. We recognize that emphasis on increasing STEM teacher effectiveness and confidence is required to increase student outcomes. Therefore, all activities as part of course content redesign will include parallel support and training for teachers (Appendix J, Table 5). ESI goals and activities are strategically aligned to address Absolute Priority 3, Subpart (a).

B2. Clarity and Coherence of Project Goals

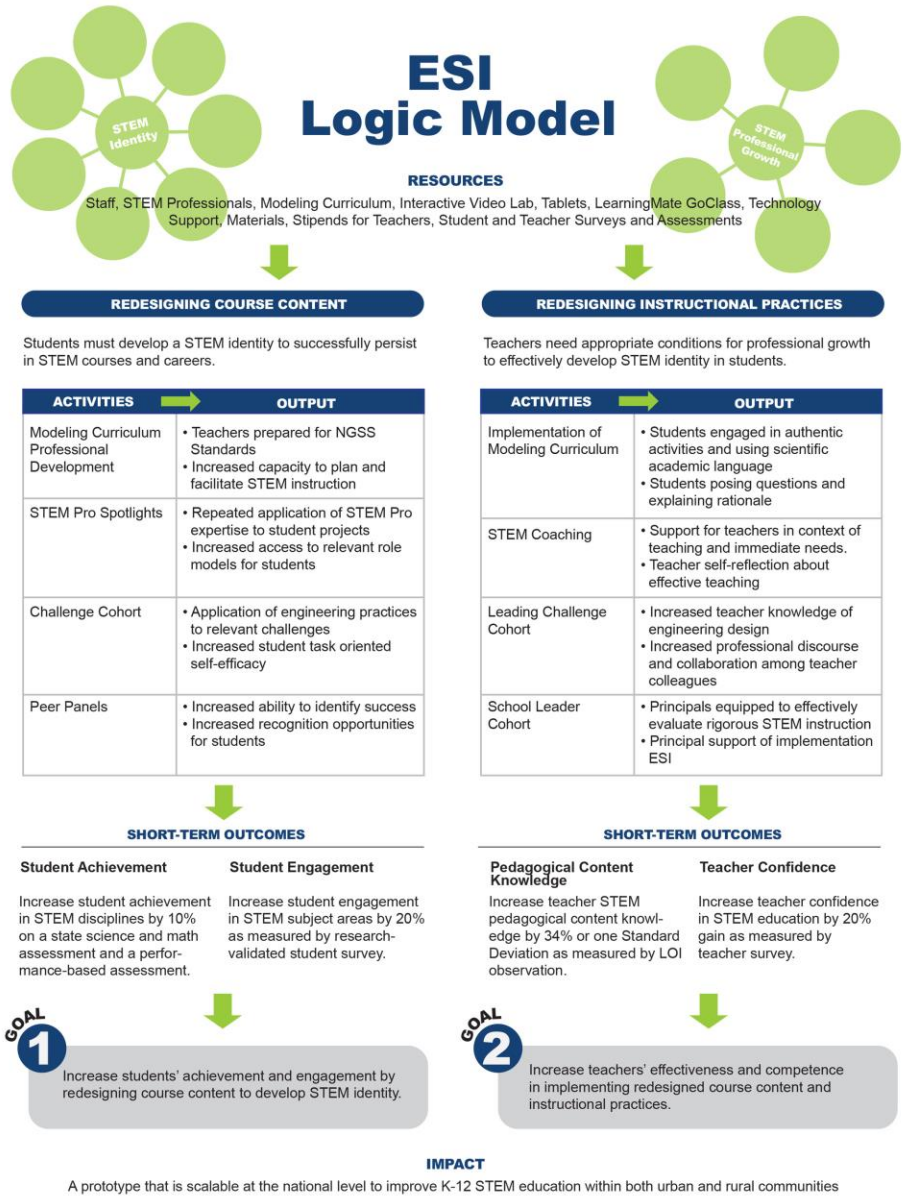
Goal 1. Engineering STEM Identity (ESI) is a model that redesigns student experiences in STEM courses by providing opportunities for students to engage in meaningful STEM challenges, learn through research-based curriculum, access relevant role models, and recognize peer successes. (Absolute Priority 3)

Goal 2. The ESI model empowers teachers to implement redesigned course content and utilize instructional practices to maximize student learning in their classrooms. This model engages teachers in research-based professional development to support curricular planning, provide access to pedagogical content experts and STEM professionals, and develop administrators as a resource for institutional change. (Absolute Priority 3)

Engineering STEM Identity (ESI)

Together, these goals build Engineering STEM Identity, a model for improving STEM education to address the national shortage of STEM professionals. The ESI method of delivery, using the Interactive Video Lab (IVL), tablets, and a Learning Management System (LMS), is significant because it provides a platform that can be scaled up and generalized in classrooms across the nation. Key resources for program implementation will ensure that obstacles are anticipated and mitigated. The activities address needed changes to STEM content to meet student needs to develop STEM identity. Short-term outcomes match grant objectives, and outcomes are the goals of the grant (Figure 2).

Figure 2: ESI Logic Model (Appendix D & J)



B3. Clarity and Coherence of Project Activities

Redesigning STEM Course Content to Engage Students and Increase Achievement (Goal 1)

Two activities support Objective 1.1: Challenge Cohorts and Modeling Curriculum. Challenge Cohorts provide an opportunity for classes to challenge one another to design

solutions for authentic campus needs and establish relevance of STEM disciplines to students (**curricular relevance, self-efficacy, institutional belonging**). Each cohort will consist of four classroom units that will interact with each other via the IVL. During each meeting, one class will propose a design challenge valued by students and relevant to campus needs. Other classes in the cohort will then propose designs for that challenge by engaging in the engineering design process. At the following meeting, design solutions will be presented and chosen for implementation by the original class. Student engagement with the Modeling Curriculum will further support the goal of increasing achievement (**curricular relevance, academic success)**. Modeling Curriculum engages students in Socratic questioning, where teachers guide classes towards consensus mimicking how scientists historically develop scientific models. From consensus, a full scientific model emerges with formalized assumptions and limitations, so students can apply scientific rules to other like phenomena. When limits of this model are reached, students repeat the process to develop a new model (Appendix J, Modeling Instruction).

Two activities support Objective 1.2: STEM Pro Spotlights and Peer Panels. STEM Pro Spotlights will provide opportunities for STEM role models to engage with classrooms via the IVL (**role models, gender expectations**). These role models will be chosen based on relevance to lessons and their ability to identify and inspire diverse students. Over 1,100 volunteer hours from role models will be available to teachers as part of the redesigned course. STEM Pros will interact in ways such as answering student questions, telling how they became involved in STEM, supporting content during a lesson, acting as a design project manager during challenges, or informing students about STEM fields. Recruitment of these STEM Professionals will be supported by industry partnerships such as MCESA's sustaining partnership with Engineering Build Day where, annually, STEM Professionals have been recruited by partner organizations

and trained at MCESA to visit classrooms and engage students in hands on STEM experiences. Student participation in informal Peer Panels will further increase the development of student STEM communities (**recognition, self-efficacy**). During Peer Panels, classrooms will interact via IVL on a monthly basis to share accomplishments in which they take pride and ask questions to gain feedback. Each classroom will be paired with another class to showcase projects or accomplishments.

Redesigning Instructional Practices to Improve STEM Education (Goal 2)

Two activities support Objective 2.1: Modeling Workshops and STEM Coaching. Modeling Workshops support teachers in learning the Modeling Curriculum as described in the previous section (**declarative PCK, procedural PCK, conditional PCK**). The Modeling Workshops, facilitated via IVL and provided during three weeks of summer professional development, will support teachers in developing pedagogical content knowledge (PCK) in alignment with NGSS as well integration of math and science. Kits of required materials and equipment will be constructed in advance and sent to participants so that they have the required materials to engage in live, interactive professional development via IVL. To establish teacher proficiency in the technology associated with the IVL and tablets, a two-day Kick Off will be hosted at MCESA. During the Kick Off, teachers will meet project staff, develop relationships with their cohort, and begin training and support on Modeling and interacting in an IVL and tablet environment to ensure proficiency with the technical equipment and to maximize their learning in this new delivery environment. Following the first year, participation in the Modeling Workshops will be reserved for new teachers and returning teachers requesting additional support. STEM Coaching will be available to support teachers throughout the year with monitoring and developing PCK (**declarative PCK, procedural PCK, conditional PCK, self-**

regulation). A STEM Coach will observe classrooms and engage in coaching conversations on site and via IVL. STEM Coaching will support teachers in feeling connected to resources, self-regulating their practice, and receiving differentiated support to increase PCK.

Two activities support Objective 2.2: Leading Challenge Cohorts and School Leader Cohorts. Leading Challenge Cohorts occur prior to Challenge Cohorts via IVL (**conditional PCK, self-efficacy**). Teachers will meet to narrow design challenges that will be relevant to the curriculum and maintain fidelity to standards. During the Leading Challenge Cohorts, a pedagogical content expert and STEM professional will support teachers in the content and guidance of their students towards success throughout the design process. Additionally, Leading Challenge Cohorts will support cross-disciplinary collaboration among subject area teachers. By creating an environment for teachers to engage in discourse and share challenges, teachers are more likely to engage in the implementation of new curriculum and instructional strategies (Melville, 2013). Facilitation of School Leader Cohorts will empower administrators to become agents for change by supporting teachers in redesigning instructional practices (**self-efficacy, conditional PCK**). Leaders, a PCK expert, and Program Director will meet via the IVL once per quarter. By engaging administrators using the same technological platform as for teachers, administrators are better able to mediate school-level factors to maximize STEM effectiveness.

By utilizing the IVL for professional development, ESI will provide a model for disseminating professional development materials for teachers to maximize pedagogical content knowledge in rural and remote areas. Teachers are provided professional development to learn Modeling Instruction during a three-week Modeling Workshop. During workshops, teachers are immersed in and practice interactive guided inquiry techniques while exploring pedagogical content knowledge associated with the curriculum. Acting as students, the teachers are led through the curriculum and experience instruction from a student's perspective. The facilitator

creates a classroom experience by developing participant content knowledge and managing the classroom. Teachers are grouped into cohorts, participating in the training via IVL which allows them to view the presenter, engage with professionals in person and connect with other cohorts. Experiencing the curriculum and instruction as a student provides an exemplar for teachers to replicate in their own classroom environment. Potential risks and strategies to alleviate these barriers have been identified (Table 2).

Table 2: Barriers and Solutions

Barrier	Strategy	Solution
Distance Challenges: • Availability of resources	IVL, Tablets	• The IVL brings resources to educators and students in rural communities without travel expenses (PD, STEM pros, etc.) • Tablets support differentiation and small group facilitation through the IVL. They also provide curriculum delivery.
Teacher Challenges: • Lack of confidence • Teacher evaluation implications • Institutional barriers • Relationship building through distance learning • Content misconceptions	STEM Coaching, School Leader Cohorts, IVL Kick Off, Modeling Workshop Cohorts,	• STEM Coaching addresses lack of confidence, content misconceptions, and facilitates subject area integration • School Leader Cohorts clarify evaluation implications and uncover and help overcome institutional barriers • Kick Off focuses on relationship building so that teachers learn how to maximize interaction through the IVL • Modeling Workshop Cohorts gives teachers opportunities to go to a nearby site and engage in Modeling Workshops via the IVL with another teacher
Technology Challenges: • New technology • Malfunctioning equipment • Insufficient bandwidth	Kick Off, IVL Support Documents & Reporting Protocol	• Kick Off trains teachers on new equipment • IVL Support Documents provides protocol for reporting challenges • Obtain bandwidth
Curriculum Challenges: • Parental concerns • Administrator backing • Access to materials	Parent Night, School Leader Cohort, IVL Kick Off	• Parent Night engages parents to provide access to staff & activities • A kick off for administrators introduces ESI curriculum • School Leader Cohorts inform administrators of program changes • IVL Kick Off provides teachers required materials

C. Quality of Management Plan

C1. Responsibilities, Timeline, and Milestones

The project timeline below articulates key responsibilities including timelines and milestones for completion of the project activities, metrics used to assess progress on an ongoing basis and annual performance targets used to monitor goal achievement.

Goal 1: By 2016, increase 2300 students' achievement and engagement by redesigning course content to develop student STEM identity.			
Objective 1.1 Increase student achievement in STEM disciplines by 10% on a state science and math assessment and a performance-based assessment.			
Activities	**Timeline**	**Responsibility**	**Metrics**
Establish internal advisory team and staff	Jan 2014	PD, ASEI, MCD	Management plan & reporting protocol
ASC vets internal management plan	Jan 2014	PD, IAT, ASC, MCD	Minutes of STEM Commission and modified plan
Milestone: Vetted Internal Management Plan by February 28, 2014			
Conduct monthly IAT and management team meeting to review progress, obtain feedback, and make modifications to ESI Project.	Feb 2014, monthly	IAT, PD, Staff	Management plan completion data and adjustments
Complete procurement of Modeling Curriculum, assessments, and EE	Feb 2014	PD, IAT, ASES, AIC	Review all curriculum, assessments, and metrics with EE
Hire internal and external staff	Feb 2014	PD, IAT	Human Resources staff records
Complete procurement of IVL equipment	Feb 2014	ASES, AIC, MITS, RTS	Complete set up. testing & troubleshooting protocol
Complete procurement of tablets and load GoClass application	Feb 2014	PD, ASES, AIC, MITA, MITS, SC	Inventory & testing of teacher tablets & software
Inventory and procure equipment to support Curriculum, annually	March 2014	SC, SPCE, ASES, AIC	All resources boxed for teacher distribution
Milestone: Procure curriculum, technology and hire ESI Project staff by March 31, 2014			
Implement Modeling Curriculum	Aug 2014	PD, SPCE, SC	Student work samples
Implement Challenge Cohorts for student design challenges	Feb 2014	PD, SPCE, SC, SP, IAT	List of Challenges & resulting designs
Develop evidence-based assessment prototypes for Jan 2015 field test	Aug 2014	PD, SPCE, SC, AT	Blueprints, evidence tables, tasks, cognitive labs
Annual Performance Target: 90% of students complete Challenge Cohort quarterly design challenges.			
Identify match comparison student group	March 2014	PD, ARE, EE	Data records
Collect and analyze student state level assessment. Annually	August 2014	PD, DC	Data spreadsheet
Milestone: External Evaluator quarterly report to Internal Advisory Team, ESI Staff, and STEM Commission to implement program revisions. (June, Sep, Dec, March)			
Annual Performance Target: Modeling Curriculum units implemented. 100% of students achieving 75% on Modeling Curriculum formative assessments.			
Identify math gaps aligned to curriculum and Common Core standards	June 2015	SPCE, SC, MC	Crosswalk Modeling, math curriculum
Implement math interventions aligned to Modeling Curriculum	July 2015	SPCE, SC, MSC	Observation data using Math Evidence Guides
Provide PD in Common Core Literacy for Science & Technical Subjects	July 2016	SPCE, SC, ESC	Observation data using Common Core Evidence Guides
Objective 1.2 Increase student engagement in STEM subject areas by 20% as measured by research validated student survey.			
Continue STEM Professional requirements, enlistment process.	Jan 2014	PD, IAT, SC	List of STEM Pros with assignments
Annual Performance Target: 100% of classrooms have STEM Professional.			
Present STEM Parent Night with parents and students via IVL	Sep 2014	PD, SPCE, SC, IRS	Class rosters of students and parents
Implement STEM Pro Spotlights	Oct 2014	PD, SPCE, SC, IRS	Meeting minutes
Implement Peer Panels to present results of student design	Dec 2014	PD, SPCE, SC, IRS	Completed protocols for Peer Panels
Annual Performance Target: 100% of student groups present results of student design to STEM Pro.			

Goal 2: By 2016, increase 32 teachers' effectiveness and confidence in implementing redesigned course content and instructional practices.			
Objective 2.1 Increase teacher STEM pedagogical content knowledge by 34% or one Standard Deviation as measured by LOI and BECI content assessment.			
Plan Kick-off Event for teachers. Include baseline BECI.	Feb 2014	PD	Agenda, Training Materials
Complete baseline LOI evaluation via IVL.	March 2014	SC, SPCE, EE	Evaluation data
Annual Performance Target: 100% of teachers take BECI & baseline LOI			
Conduct Modeling Workshop via IVL, annually for new teachers.	July 2014	MCS, PD, SPCE, SC	Stipend documentation, PD Rosters, BECI & STEBI data
Provide troubleshooting training and support for IVL and tablets	July 2014	SC, IRS	FAQ, Protocol, Videos Training Clips
Milestone: Complete summer institute, 100% teacher participation, prepare teachers for technology use, demonstrate proficiency with IVL & tablets			
Implement STEM coaching cohorts	Oct 2014	PD, SPCE, SC	Cohort groups, data, goals, evidence
Implement Leading Challenge Cohorts	Jan 2015	SPCE, SP, SC	Challenge Cohort Meeting dates
Provide PD for teachers in Arizona Common Core Standards for Math	March 2015		
Annual Performance Target: 100% of teachers participate in STEM Coaching Cohort and Leader's Challenge Cohort.			
Objective 2.2 Increase teachers' confidence in STEM education by 20% gain as measured by teacher survey.			
Meet with administrators to develop expectations and project timelines	Feb 2014	PD, SPCE, SC, EE, IAT	Rosters
Present District Leader Kick-off and Planning Seminar	March 2014	PD, SPCE, SC	Agenda, Presentation
Develop resources and protocol for IVL technological support.	March 2014	IVL, SC	Protocols and Documentation, Videos
Milestone: Complete leader kick-off and technology/resource support and dissemination			
Notify teachers of project timelines & cohorts.	April 2014	PD, SPCE, SC	Meeting Summaries
Host initial STEM teacher cohort collaboration using IVL equipment.	April 2014	SC, IVL	Documentation from Teacher Kick-off Event
Support proficient IVL use & provide ongoing technical support	May 2014	IVL, PD	Data of IVL issues per teacher
Establish School Leader Cohort	Oct 2014	SPCE, SP, IRS	Meeting dates, School Leader Cohort protocol
Annual Performance Target; All teachers participate in Leader Challenge Cohort with support of STEM Pedagogical Content Expert and STEM Coach through IVL			
Establish District and Site Leadership for PCK support, August, November, February, May	Aug 2014, annually	PD, ASEI, SPCE, SC	Meeting Summaries
Dissemination and Advancement of Theory			
Develop sustainability plans for districts	Aug 2016	PD, SPCE, SC, IVL	Formal Sustainability Strategic Plan completed
Prepare publications, submit to journals & national conferences	Aug 2016	SD, PD, SPCE, DC	1 publication, 2 completed conference presentations
Submit summative report	Dec 2016	PD, IAT, EE, MCD	Submitted report
Annual Performance Target: Presentation at conferences and publication in peer-reviewed academic journal			
Annual Performance Target: Implemented Sustainability Plans in districts			
Project Staff Abbreviations: Project Director = PD, Internal Advisory Team =IAT, Arizona STEM Commission = ASC, STEM Director = SD, STEM Pedagogical Content Expert = SPCE, IVL & Resource Specialist = IRS, External Evaluator = EE, Chief Deputy of MCESA = MCD, Assistant Superintendent of Education Innovation = ASEI, Assistant Superintendent of Economic Services = ASES, Administrator for Innovation and Compliance = AIC, Administrator for Research and Evaluation = ARE, Assessment Coordinator = AC, Data Coordinator = DC, MCESA IT Administrator = MITA, MCESA IT Specialist = MITS, Modeling Curriculum Staff = MCS, Math Standards Coordinator = MSC, Assessment Team = AT, STEM Coach = SC			

C2. Commitment of Key Partners

ESI recruited LEAs based on the demographic characteristics of high poverty from both urban and rural areas. Partners were then selected by considering teacher attrition rates, and expressed interest in STEM initiatives. The goals will be carried out in 10 LEAs serving 2300 students and 32 teachers (Appendix G).

Table 3: LEA Partner Description

LEAs	# of Students	# of Science Teachers	2013 Math AIMS % Passing	2013 Science AIMS % Passing	% Free & Reduced Lunch
Aguila Elementary	35	3	70	69	92.31
Arlington Elementary	91	3	51	47	85.60
Bagdad Unified	95	2	51	40	53.24
Balsz Elementary	764	3	57	40	91.20
Mobile Elementary	6	3	70	38	72.97
Morristown Elementary	42	3	54	53	75.00
Paloma School District	32	1	39	17	73.33
Saddle Mountain Unified	313	4	56	47	70.86
Salt River Pima	84	1	20	23	69.44
Tolleson Elementary	835	9	52	47	84.29
TOTAL	**2297**	**32**			

MCESA will bring STEM education resources to partner LEAs as shown in the Logic Model (pg. 9). By incorporating private partnerships, LEAs may leverage support from these sources beyond the period of the grant as relationships between students and engineers can be maintained outside of ESI. Teachers from Year 1 will be trained and supported to be able to continue Modeling Workshops for new science teachers in other LEAs. In Year 3, MCESA will work with districts to find resources and adapt ESI beyond the life of the grant.

An alliance of private sector STEM Commissioners will be formed to provide financial support as well as technical support for the project by reviewing program data, accomplishments, and barriers to success to extend their influence and resources to mitigate obstacles. MCESA's first STEM Commissioner, LearningMate Solutions, Inc., will contribute a learning management system to enhance the tablet solution. The system will support differentiated, collaborative work

via the IVL as it allows multiple participants to work on the same or varied problems simultaneously, live, from multiple locations.

C3. Project Feedback and Improvement

Tracking progress is an important part of ESI to ensure that meaningful improvements are made in a timely manner. Stakeholder groups of teachers, principals and STEM Commissioners will share feedback regarding scheduling, teacher confidence, cohort groupings, and STEM Pro effectiveness to provide input and data on the effectiveness of program implementation. Using feedback, teacher cohorts may be changed to alleviate scheduling issues or additional challenges. External evaluator and data coordinator will provide measurement data, both qualitative and quantitative reports (see Evaluation) to the internal advisory management team quarterly to track progress against establish measures. The internal advisory management team will make ongoing adjustments to program to support successful completion of goals.

D. Personnel

MCESA has direct and relevant experience that will support the successful implementation of ESI. Specifically, using IVL, MCESA directly delivered science content instruction from a highly qualified teacher when the school was unable to hire one. Student achievement data showed stagnate science scores on AIMS prior to MCESA support. Following the intervention, students showed a significant gain of ten percentage points (Appendix C). This model demonstrates the ability to impact student learning through IVL and potential for use in professional development to outlying populations.

ESI requires programmatic evaluation using teacher observation instruments to measure teacher effectiveness. MCESA has demonstrated success in supporting high needs districts in the development and use of observation tools to reliably measure educator effectiveness through implementation of Rewarding Excellence in Instruction and Leadership (REIL), a five-year

$51.5 million Teacher Incentive Fund grant and a second Cohort 4, five-year $59 million TIF grant from US Department of Education. ESI provides content integration training to teachers. MCESA has also successfully provided Common Core Training and integration within other content areas to 3,000+ educators with course evaluations average scores of 4.8 out of 5.0. Additionally, MCESA is equipped to support assessment development within the ESI program. MCESA has developed valid and reliable assessments for the non-tested subjects and grades to measure educator effectiveness. To support assessment development, 367 teachers and administrators representing 51 LEAs developed assessment blueprints, item specifications, and items to support the development of over 54 assessments. Together, these MCESA programs have resulted in creating and implementing systemic and sustainable approaches to support teacher innovative instructional practices, educator evaluation, assessment development, and professional development (Appendix C).

Responsibilities of Key Personnel

Key personnel will include a Project Director, STEM PCK Expert, STEM Coach, IVL Media Specialist, and Data Coordinator. The **Project Director** (1.0 FTE) will be responsible for coordinating all activities under each of the program objectives, ensuring efficient coordination and communication across program partners as well as oversight of the day-to-day operations, supervision of the program staff, successful completion of annual grant requirements, and collaborative work with the internal advisory team, LEAs, and project partners.

The scope of this project will require additional personnel to assist with program implementation: a **STEM Pedagogical Content Expert** (1.0 FTE), whose expertise in both STEM educational theory and content will serve as a resource for teachers, support the STEM coach, coordinate STEM professionals, and act as a liaison between industry professionals and classroom teachers; a **STEM Coach** (1.0 FTE), who will collect teacher evaluation data, implement ongoing differentiated professional development for teachers, and communicate

teacher feedback to internal management team; an **IVL & Resource Specialist** (1.0 FTE), who will be the technical facilitator of IVL activities and provide technological assistance to teachers and partners; and a **Data Coordinator** (1.0 FTE), who will collect and analyze project to provide formative feedback to the internal advisory team (Appendix F).

MCESA's Internal Advisory Team (IAT) will be responsible for recruiting and staffing ESI. Until full-time staff has been hired, each member will fulfill responsibilities of project staff to ensure that critical work will proceed.

Dr. Jacquelyn Kelly, STEM Administrator. Dr. Kelly's undergraduate degrees in physics and chemistry, M.S. in Materials Science and Engineering, and Ph.D. in Science Education paired with 9-16 teaching experience give her a unique perspective in connecting theoretical education research with practice in the K-16 system. She worked on multiple NSF funded engineering education grants, presented findings at national conferences and in academic peer-reviewed journals. Dr. Kelly will provide support to the Project Director and provide crucial input on STEM content and educational theory. Prior to filling staffed positions, she will act as the Project Director while utilizing her expertise in STEM pedagogical content knowledge.

Dr. Susan Haag Director of Research and Evaluation. Prior to MCESA, Dr. Haag worked for Arizona State University as the Director of Evaluation and Assessment of Fulton School of Engineering where she also was the Assistant Vice Provost for STEM Initiatives. Dr. Haag currently collaborates with administrators across MCESA to review and evaluate PK-12 education programs and work with external evaluators to complete internal and external program evaluation.

Candace Diehl, Administrator for Standards and Assessment. Ms. Diehl has over 35 years of experience developing curriculum for K-12 education, coaching teachers and training principals. Presently leading MCESA's STEM, Common Core and Assessment implementation projects, her understanding of school district structure has informed the development of ESI and will

continue to inform changes to the program. She will support ESI by assisting in acquiring the curriculum and planning the professional development workshops prior to the STEM Director and STEM Expert being hired.

Dr. Lori Shough, Assistant Superintendent for Education Innovation – Dr. Shough collaborates with state agencies, such as the Governor's Office of Education Innovation and the Arizona Department of Education, and other Regional Centers in Arizona to develop and implement state-wide strategic planning for Arizona's Race to the Top grant and Common Core Standards implementation. Prior to MCESA, she has served as Assistant Superintendent for Curriculum and Instruction in two school districts where she developed and delivered differentiated professional development.

Kristine Morris, Chief Deputy Superintendent. Responsible for the overall direction and management of administration and operations for MCESA acts on behalf of the Superintendent of Schools in high-level meetings with County officials, the public, legislators, and the media. Ms. Morris served in district and site leadership roles and as PI for both NSF and Teacher Incentive Fund Grants. Ms. Morris will serve on MCESA's STEM Commission, plan for sustainability and monitor and communicate the impact of existing and proposed legislation on ESI.

E. Quality of Project Evaluation

E1. Project Evaluation Design and Questions to Determine Impact and Fidelity

ESI evaluation will assess the impact of the program on the development of a STEM identity of high-needs students by increasing their achievement and engagement using redesigned science content. ESI will provide related STEM professional development to 32 teachers to increase their effectiveness and confidence in science content to impact instruction for 2300 students. This quasi-experimental, matched comparison group design uses multiple data sources, mixed methods, and statistical tests to measure progress toward meeting the established

outcomes and to answer the three evaluation questions as outlined in Table 4. ESI's logic model (Figure 2) clearly aligns program design to program outcomes studied in the evaluation. An *impact study* will measure effects of project activities on student achievement and teacher performance through the use of qualitative/quantitative measures (Question 1 and 2). The *implementation* study will determine program fidelity, and findings will provide program leadership with ongoing, formative feedback (Question 3). Data provided will validate that the project activities and professional development are on track to meet ESI goals. ESI has identified the expected changes/improvement; appropriate measures have been selected for tracking changes; and a process established to collect reliable data to indicate success as summarized in Table 4 (Desimone, 2002; Desimone, Smith, Baker & Ueno, 2006; Desimone, 2009)

E2. Evaluation Plan with Sample Size, Effect Size, and Analytic Approach

ESI will conduct both an implementation study and an impact study, providing immediate feedback on reaching program goals to facilitate continuous improvement and impact.

Student Impact Study. ESI's evaluation will assess the impact of the program on students through Evaluation Question 1: To what extent does ESI increase student achievement and engagement in STEM disciplines by developing STEM identity? ESI will implement a **quasi-experimental, matched comparison group design** using multiple methods and statistical tests to measure progress toward outcomes and answer the evaluation question. This model provides a good alternative, as a randomized controlled trial is not feasible. By employing a given threshold used to determine treatment (e.g., scoring below proficiency on the science AIMS test), an a priori power analysis suggested that a treatment group size of at least 787 will have a 80 percent chance of detecting a **small effect size** (.10) (Ferguson, 2009). The project sample population exceeds this recommendation. The evaluation will consist of qualitative and quantitative methods

allowing for detection of both intended and unintended impacts. *The Teacher Impact Study* will address Evaluation Question 2: To what extent does ESI increase teacher effectiveness and confidence in implementing redesigned course content? Teacher impact will be measured through an energy concept inventory (BECI), a science efficacy instrument (STEBI), and through observation of instruction (LOI). An a priori power analysis, conducted to determine the number of participants needed to achieve a desired power and analysis, indicated a 75% chance of detecting a moderate effect size, with a minimum sample of 30 teachers. ESI's study sample exceeds this number. A comparison group equivalent on selected demographic characteristic (e.g., time teaching, grade band) will be selected.

Data Collection and Analysis: The required state measures (AIMS) as well as additional qualitative and quantitative measures listed by objective in Table 4 are used to show impact of ECI on student achievement and teacher effectiveness. Aggregate results in a summary narrative format as areas of strengths and improvement will be shared. The *Basic Energy Concept Inventories (BECI)* pre-post *t*-test will be used to measure teacher knowledge of core content concepts and will be analyzed for project and comparison groups (prior to any professional development for the participant group). Statistical analysis will determine differences between the ESI teacher group and the comparison group.

While AIMS student data was used to determine the project need, AIMS (state science and math assessment) pre- and post- data will be used in the evaluation to support the objective related to student achievement. Data will be analyzed two ways. First, a *t*-test will be used to evaluate whether there are difference in scores between the participant and comparison group pre/post.

Table 4: Evaluation Implementation and Impact Study				
	Measure- & Threshold	**Description-Frequency & Purpose**	**Anticipated Timeline for Data Collection**	**Data collection & analysis- (**t-test & comparative analysis**)**
Evaluation Impact Question 1: To what extent does ESI increase student achievement & engagement by developing STEM identity? (Goal 1)				
Objective 1.1 Increase student achievement in STEM disciplines by 10%	*AZ State 8th grade science & math assessment; 7th grade math assessment*	Pre-post; beginning of project prior to PD (2014); at the end of project following all PD **Student Impact**	Beginning and end of academic year (data collection every August 1; pre-post for math, starting August 1, 2014; annually	Data collection- Baseline and end of year data collection (Internal); Data analysis: External Evaluator
Objective 1.2 Increase student engagement by 20%	*STEM-BAS** *Threshold 20% or .5 SD*	Online- Pre-post; beginning of project prior to PD and at end of project following all PD **Student Impact**	*STEM-BAS* Survey administered 8/ 14, 15, 16 (pre) student cohort; post starting 5/2015 and then annually for each student cohort	*STEM-BAS* administered online by Internal Evaluator; analysis conducted External Evaluator (pre-post analysis/annually)
Evaluation Impact Question 2*:* To what extent does ESI increase teacher effectiveness & confidence in implementing redesigned course content? (Goal 2)				
Objective 2.1 Increase teacher STEM pedagogical content knowledge by 34%	*LOI-Learning Observation Instrument*	Pre-post; beginning of project prior to PD; at end of project, annually/ (5/2014 pre, and 5/2015 post) **Teacher Impact**	Annually: before and after program intervention (spring 2014 and following spring 2015); pre-post data collected annually	*LOI* collected by ESI team (Internal); Data analysis: External Evaluator-
	BECI-Basic Energy concept Inventory *Threshold 34% or 1 SD*	Pre-post; beginning of project prior to professional development; end of project to measure knowledge of core concepts **Teacher Impact**	Beginning of project prior to PD and at the end after PD (7/14- 5/16); Annual report each year (progress monitoring reports-quarterly to ESI IAT)	BECI data (pre and post) collected by ESI team. Data analysis by External Evaluator-annually; External Evaluator
Objective 2.2. Increase teacher confidence in STEM education by 20% as measured by teacher survey.	*IAT meeting notes; Evaluator Notes*	*Evaluator's PD notes*; Examine self- confidence observed during PD **Teacher Impact**	On-going throughout project	Evidence of positive growth in confidence –qualitative data (External Evaluator)
	*Science Teaching Efficacy Belief's Instrument*** *Threshold 20% or .5 SD*	Online - Pre-post; beginning of project prior to PD & at end of project following all PD. **Teacher Impact**	Summer Institute (June 2014 and post-5/2017 for teacher cohort)	*STEBI* data (pre-post) collected by ESI team (Internal); Data analysis: External Evaluator-annually; quarterly Progress report, ESI team
Evaluation Implementation Question 3: How can the program be refined to better support and enhance teacher PD, administrative leadership, and student achievement? [What are the strengths of this particular ESI model in comparison to other designs -summer-institute only, Saturday sessions only, technical assistance, etc.]? (Goal 1 & 2)				
Fidelity of the Program: The project evaluator will identify factors that facilitated better support and enhanced teacher PD administrative leadership, and student achievement	*Evaluator's notes* *Internal Management Meetings*	Evaluator's observation notes taken during PD; Collaboration: Evaluator & ESI Project Director as a result of IAT meetings for improvement. F**ormative/ implementation;** Ongoing Evaluator Notes: collected during all PD. **Formative/Summative**	On-going throughout project; Immediately following first PD 7/2014 session; ongoing-formative assessment- 2016 Internal Advisory Team meetings; Evaluator Notes-written during PD and other meetings distributed during the program—provided for ESI IAT	Data analysis (External) to determine evidence of factors that contribute to the high-quality PD; examine partner accounts, including leader input, & teacher accounts of success; reported quarterly to ESI team; Summative Report-External Evaluator-end of program

*STEM-BAS, (Fouad, Hackett, Smith, Kantamneni, Fitzpatrick, Haag, & Spencer, 2010), **STEBI (Enochs & Riggs, 2002)

Secondly, a paired samples t-test will be used to examine difference within the participant group pre- to posttest to determine program efficacy. Qualitative data will be ongoing through Evaluator Notes collected during training and other meetings. Similar analyses will be conducted for all survey data.

E3. Outcomes of the Project and Implementation Study: Implementation Study

The ESI evaluation plan has identified key components and outcomes of the project and articulates a measurable threshold for an acceptable implementation (Table 4). The study of impact and implementation will provide program leadership with ongoing, formative feedback. Data provided will validate that the project activities, including professional development, are of high quality, on schedule, and are likely to result in the attainment of the broad goals and objectives. Using available state assessment data, student achievement progress will be monitored throughout the grant period. Interim reports will be provided to inform practice and to increase the impact of the program. Summary data identifying goals met/not met will be provided each year. These analyses will be based on student achievement, STEM engagement, and identity. Indicators of progress (e.g., on track to meet goals, not quite on track to meet goals, and not on track to meet goals) will be provided to help staff prioritize and address needs. Feedback will be provided to leadership through a variety of methods to ensure timely modifications to project activities.

External Evaluator. To ensure a rigorous third party evaluation of the ESI, an external evaluator will be selected. They will have experience working directly with schools with 6th – 8th grade populations in the area of science and engineering and a background which allows them to understand the importance of incorporating science and engineering practices into the middle school science curricula. The external evaluator will be familiar with tools and processes from

prior program evaluation experience which will lend further credibility to the evaluation. The evaluator will have published in journals and presented nationally on science and engineering education, math, and STEM research topics and have extensive experience in project evaluation, methods, and quasi-experimental design. MCESA has two contracted vendors, AIR and WestEd, to be considered for this position.

Evaluation reporting by the external evaluator, will allow for the inclusion into a usable body of research and include quarterly progress monitoring summaries and formative assessment conducted and disseminated on a regular schedule. These summaries will contribute to a summative evaluation report. ESI evaluation reports will be used to inform the USDOE annual performance reporting (APR) and support the overall presentation of comprehensive program findings/conclusions; substantiate that the project has collected credible evidence to determine the extent of attainment of project goals; answer evaluation questions; and present any claims and reports on threats to the internal/external validity of the research findings. The end of project summative evaluation report will also communicate reporting on the equivalence of the groups, including at a minimum, a comparison between the groups on the teacher characteristics. The activities and subsequent evaluation of this program will build a rigorous, replicable, and usable body of findings. Methods for communication include verbal and written communication between evaluator and project management resulting from the following: 1) observation of professional development (e.g., LOI results, Evaluator Notes); 2) quarterly progress monitoring evaluation summaries; 3) project team lessons-learned meetings, and 4) evaluation reports. An Evaluation table (Appendix J, Table 7) shows timelines of data collection, analysis, and report submission.