WINCHESTER PUBLIC SCHOOLS

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Metrics: **M**aximizing **E**ngagement **T**hrough **R**egular **I**mmersion in **C**omputer **S**cience

A. SIGNIFICANCE

(1) Contribution of the Project. Our proposed EIR early-phase project, **Metrics**: **M**aximizing **E**ngagement **T**hrough **R**egular **I**mmersion in **C**omputer **S**cience, addresses ***Absolute Priorities 1: Demonstrates a Rationale*** and ***3: Field-Initiated Innovations: Promoting STEM Education with a Particular Focus on Computer Science*** and the ***Competitive Preference Priority: Expanding Access to and Participation in Rigorous Computer Science (CS) Coursework for Traditionally Underrepresented Students.*** Our vision is that a whole school immersion approach to CS integrated across the curriculum into daily classroom and real-world experiences will boost traditionally underrepresented, high-need student aspirations, attainment, and achievement. This project will create an elementary school continuum, serving as a framework for programs across the state and nation, while becoming the standard for preparing students with interest in and aspirations for a career in STEM and CS fields. Our project will contribute to the field by generating and validating solutions for the following persistent educational challenges: (1) Many states now have CS standards yet lack the teacher knowledge, instructional integration, materials, and professional development to implement the standards effectively and assess student performance in CS, especially at the elementary level;[1] (2) If districts have a CS specialist, they are often tasked with designing a CS curriculum for the entire district among teachers that lack knowledge of CS, limiting the support and understanding to implement units effectively;[2] (3) CS and computational thinking are not typically integrated across all subjects but instead provided once a week in a special class or club lacking connections to the real world;[3] (4) Access to and participation in rigorous CS coursework is limited, particularly for traditionally underrepresented students, with schools serving wealthier families being more than twice as likely to offer CS;[4] (5) Efforts to increase student participation in CS is often too late with many experiencing the "middle school cliff," starting the decline of traditionally underrepresented students, particularly females, in STEM subjects;[5] and (6) Students are not interested in pursuing CS with 58% of all new jobs in

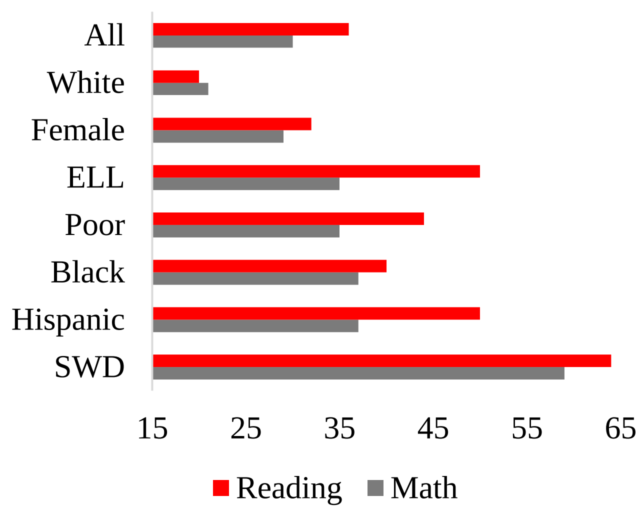
STEM focused on computing, but only 10% of STEM graduates major in CS.[6] Our research study will be conducted in Virginia which became the first state in the nation to pass sweeping CS education reform in 2016.[7] This law mandates that every K-12 student receives access to essential CS literacy, including coding. Virginia provides an ideal setting to research strategies as our state experiences many similar educational challenges in CS facing our nation:[8] (1) Our state currently has 37,493 open computing jobs which is 4.1 times the average demand rate; (2) In 2017, there were only 1,865 CS graduates, and less than a quarter were female; (3) In 2016, there were no new teachers prepared to teach CS graduating from universities in Virginia; and (4) AP Computer Science exams were taken by 5,005 students in 2018 with low percentages of traditionally underrepresented students taking the exam: 27% female, 8% Hispanic or Latino, 7% Black, and less than 1% American Indian. The **Metrics** model will be tested and rigorously evaluated in Winchester Public Schools (WPS) located in the historic and scenic Shenandoah Valley of Virginia. Our district is committed to educating and challenging every student to succeed and is guided by the mission: *Learning for All, Whatever it Takes.* Our district serves 4,368 students hailing from 27 nations and speaking 19 languages in our four Title I elementary schools, one intermediate school, one middle school, and one high school.[9] Our diverse community is a microcosm of our state and nation based on the similar demographics in Table 1, and our district minority as majority demographics (below) are representative of what our country will look like over the next 20 years,[10] making our district an ideal setting to test, study, refine, scale, and sustain replicable strategies for traditionally underrepresented students in STEM and CS.

Table 1. Community Demographic Data by Percent (2018)[11,12]

Indicator	WPS	Winchester	Virginia	USA
White alone not Hispanic	41	66	62	61
African American alone not Hispanic	11	12	20	13
Hispanic or Latino	37	17	9	18
Persons in poverty	83	13	11	12
High school graduate or higher age 25 +		84	89	87
Bachelor's degree or higher age 25 +		33	38	31

Our field-initiated innovations will be tested at two K-4 schools, Garland Quarles Elementary and John Kerr Elementary, as they provide a strong setting to test strategies that improve student achievement and attainment: (1) These schools serve 914 students with a traditionally underrepresented student population where nearly 31% of students speak a language other than English as their first language, and student demographics are 38% White, 41% Hispanic, 10% Black, 7% Multi-Racial, and 4% American Indian.[13,14] (2) Serving high-need students, both schools are Title I with a free- and reduced-lunch rate of 83% and are under the USDA Community Eligibility Provision which enables the nation's highest poverty schools to serve breakfast and lunch at no cost to all enrolled students without collecting household applications.[15] (3) As noted in *Figure 1*, standardized test scores in math and reading (students are not tested in science until 5th grade) for students at our target schools demonstrate gaps among traditionally underrepresented subgroups with opportunities for academic growth through **Metrics**.[16] (4) Since 2017, both schools have been designated as STEM-themed programs providing a strong basis to integrate CS curriculum units and instructional practices. Further, every student in the attendance zone goes to these schools which helps reduce selection bias and increase the number of traditionally underrepresented students participating in CS and STEM coursework.

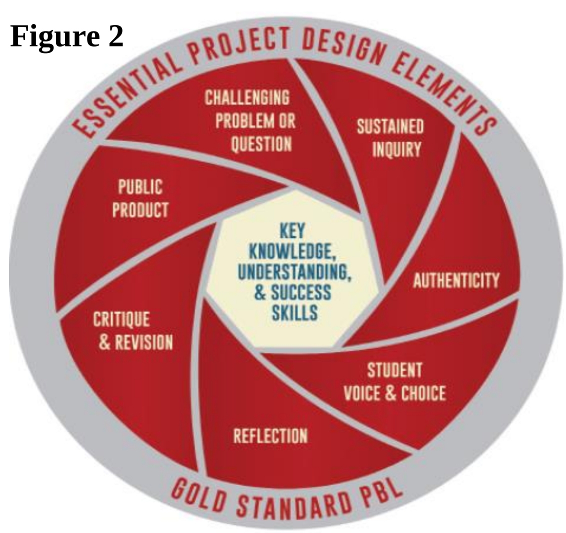
Figure 1. Percent of Students <u>Not</u> Passing



(2) Promising New Strategies. Through a whole-school immersion approach, our model will focus on three integrated field-initiated innovations at the elementary level: (1) Creating rigorous CS curriculum units and assessments to support STEM coursework connected across all subjects through problem-based learning; (2) Providing a high-quality teacher development and support process to sustain innovative CS instructional practices; and (3) Strengthening students' tethers to CS and STEM coursework by engaging students, with a focus on traditionally underrepresented minority and female students, in real-world linkages beyond the classroom.

◆**Strategy 1: Creating Rigorous CS Curriculum Units and Assessments:** The 2017 CS Standards of Learning for Virginia Public Schools classifies academic content for key elements of the CS curriculum at each grade level.[17] Our district is one of five LEAs in the state selected as a partner with CodeVA, a nonprofit focusing on equitable CS education by preparing schools to launch the new standards. These rigorous standards were developed based on expert knowledge from entities such as the Computer Science Teachers Association, K-12 Computer Science Framework, and the College Board AP Computer Science. Designed to be integrated into instruction in multiple subject areas, the content strands include six high-need areas: Computing Systems, Networks and the Internet, Cybersecurity, Data and Analysis, Algorithms and Programming, and Impacts of Computing. These standards will be used as a framework to develop CS units, pacing guides, instructional sequences, and performance-based assessments for each grade level, ensuring they are vertically and horizontally aligned. During *Phase 1* of development (*11/19-2/20*), an initial Core Team of K-4 teachers and staff will examine the standards and design a plan on how to integrate CS standards and performance-based assessments across the curriculum and standards of learning as well as assess digital tools to support learning. Our curriculum design cycle from the Buck Institute for Education in *Figure 2* will be driven by teacher development, student interest obtained via surveys, relevance to national and global issues, and fit to

Figure 2



state CS standards.[18] A key focus will also be on designing units that are representative of and enticing to females and minority students. The team will review resources from CodeVA and Code.org including their curriculum guide, Common Sense Education K-12 Digital Citizenship Curriculum Scope and Sequence, and Computer Science Frameworks from the Shenandoah Valley Technology Council as well as seek input from other districts. During *Phase 2 (3/20-8/20)*, the curriculum plan will be piloted with a small group of four teachers across each grade level and revised as needed based on teacher and student feedback. Our vision and plan will then be introduced to all staff as well as to parents and community members through CS nights, family letters, and social media. In *Phase 3 (9/20-10/20)*, the curriculum will be rolled out to the entire staff so that all teachers integrate CS and STEM standards and assessments into instruction supported by professional development outlined on page 7. In *Phase 4 (starting 11/20)*, as teachers become comfortable with CS standards, community partnerships to extend hands-on learning will be incorporated for real-world experiences. Finally, in *Phase 5*, *(starting 1/21)* we will continue to provide professional learning opportunities that ensure high-quality implementation of CS units. Providing student synergy and engagement, CS units will be integrated across courses, so students explore the same issue in every subject area through problem-based learning focused on computational thinking and interdisciplinary problem solving. For example, one CS Standard of Learning states that *"the student will construct programs to accomplish tasks as a means of creative expression using a block-based programming language or unplugged activities, by using sequencing and loops and identifying events."*[19] In our algorithm and programming CS unit, science class conducts inquiry based assessments on growing patterns for hydroponic plants used as a filtration system in their aquarium; math class researches and conducts ongoing graphic representations of the hydraulic flow and power source needed to loop water through the system to grow the most effective agriculture from the aquarium; history class examines how other cultures address hydration systems for food sources in climates such as deserts; and English class writes detailed instructions for how to create the most effective hydroponic system to support vegetation and wildlife. STEM classes work on programming sequences through PBS Design Squad Global which helps them design a program for hydroponic systems, while art students take the designs and map them out for how to use this system in their outdoor classroom. At the end of the project, students engage in hands-on learning with community partners to address the problem (e.g., wildlife conservation of the Abrams Creek Watershed with Shenandoah University researchers, power plant filtration and cleansing issues with Winchester City Public Utilities). The following will support delivery of each instructional unit: (1) We will integrate high-quality *digital tools* such as CS First[20] and Scratch[21] programs as well as the use of Cubelets, BeeBots, WeDo 2.0, and virtual escape rooms to support creating applications, games, websites; using tools to manipulate data; and managing computer hardware to share, secure, and use digital information. (2) *Makerspaces* in the media center will be used for students to complete self-directed projects linked to CS units and apply knowledge from the classroom in a hands-on environment with tools such as 3D printers, laser cutters, and robotics.[22] (3) *STEM labs* will also complement instructional units with two dedicated STEM teachers to support STEM literacy using integrated projects and exploration of curriculum through questioning, brainstorming, designing, building, modifying, and presenting. (4) *PEDLE (Personalized Education & Digital Learning Experiences)* began as a pilot lab for 60 4th grade students at one target school, John Kerr Elementary, through two morning instructional blocks once a week, totaling nearly four hours. With a dedicated lab coordinator collaborating with classroom teachers, PEDLE creates opportunities for personalization of learning with a blended environment where students can interact with content in a way that best fits their needs, learning modalities, and interests. Personalization is generated between teachers and students through one-on-one conferencing, goal setting, and opportunities for student voice and choice within projects, assignments, and instruction via four physical spaces: two content classrooms, a digital lab, and a project lab. Our pilot of the PEDLE lab with 4th graders has shown that students responded positively to the survey and one-on-one conferences with teachers, especially around student-led hands-on projects. Parents have also provided positive feedback about voice and choice in student projects. Our pilot has shown initial success through increased student engagement as well as growth in the development of 21st century skills aligned with our Profile of a Virginia Graduate.[23] Through **Metrics**, we will link the activities in our PEDLE lab with our rigorous CS curriculum units and expand yearly by grade level at both target schools.

◆**Strategy 2: Providing High-Quality Teacher Development and Support Process:** We will implement a variety of elements to ensure teachers are equipped to integrate CS across the curriculum and engage traditionally underrepresented students: (1) Since the integration of CS units linked to problem-based learning represents a shift in pedagogical thinking for teachers, *CS Integration Specialists* (3 total) will be crucial to the success of this project. With expertise in CS, each specialist will have a focus area to assist with integration: traditionally underrepresented students, STEM, and personalized learning. These specialists will: guide the Core Team in the development of CS curriculum linked to STEM coursework with the expertise of our partner, Shenandoah University; ensure units and extensions are designed so they are attractive to specific groups such as girls and minority students; support professional learning communities (PLCs) in the implementation of CS units, pacing guides, and instructional sequences for each grade level; help teachers develop competency with interdisciplinary and computational thinking approaches via in-class coaching and co-teaching (monthly); and assist with the alignment of results from performance-based assessments to CS units. (2) To build capacity and sustainability and institute a train-the-trainer approach, one teacher from each grade level (5 per school) will serve as a *CS Coach*. These lead teachers will participate in professional learning to earn a certificate as a CodeVA Elementary Computer Science Coach through a week-long in-person practicum and four follow up sessions during the school year.[24] This process prepares coaches to conduct training at their school using pedagogy suited for CS instruction, instruct teachers in grade level CS content linked to standards, support PLCs, equip coaches with the tools to make informed decisions about ongoing CS curricular needs, and support the onboarding of new teachers. (3) *PLCs* will be an essential tool in the development of our approach to integrate CS and computational thinking across the curriculum. PLCs will meet at least weekly to provide adequate time to refine CS units and instructional practices, ensure horizontal and vertical alignment, and link with CS standards. PLCs will be complemented with professional learning through district technology training days (annually, 8 hours), an innovation conference in collaboration with local universities to support the rollout (1 day), and summer institutes (annually) based on teacher needs. For example, CodeVA's Launching Computer Science (K5) eight-hour training prepares teachers to assimilate CS into their core curriculum focusing on content knowledge and practical experience necessary to implement CS standards, including resources from Code.org.[25] (4) To personalize and provide meaningful learning, educators will also have the opportunity to earn four CS *micro-credentials* as competencies are developed to integrate computational thinking into the classroom which helps teachers link coding and CS to other curriculum areas.[26] These competencies include: testing and refining computational artifacts, creating computational artifacts, recognizing and defining computational problems, and developing and using abstractions. This evidence-based form of professional development will enable teachers to design individualized learning pathways in CS focused on their subject area through job-embedded, portfolio-based micro-credentials.[27] (5) Our annual five-day summer *"STEMersion"* approach will immerse teachers in industry environments with local partners such as Annandale Millwork & Allied Systems, Frederick Block, Brick, and Stone, Perry Engineering, Shenandoah Valley Westminster Canterbury Company, and Winchester Metals to assess the practical use of computational thinking, computer hardware, software design, computing principles, coding, analytics, and computer applications used in the classroom. (6) We will also host an annual *Innovation Showcase* during an in-service day for teachers to share their best practices across the district to expand knowledge within and beyond our target schools.

◆**Strategy 3: Strengthening Student Tethers to CS and STEM Coursework with a Focus on Traditionally Underrepresented Students:** We have developed a variety of extensions beyond the classroom to support student engagement and achievement with purposeful activities appealing to female and minority students. Through **Metrics**, we will study the impact of integrating these tethers with CS units. Collaboration with industry partners will be essential in developing student tethers to the real world and will be achieved by industry partners: (1) serving on the EIR Advisory Council to offer input on the development of CS integrated units, makerspaces, and STEM and PEDLE labs; (2) providing hands-on experiences for students during semi-annual field trips aligned to CS standards; and (3) offering opportunities to see strong female and minority leaders through quarterly career days to support career engagement and exploration strategies as well as guest speakers to engage and motivate underrepresented students to pursue a career in STEM and CS. These activities will be supported by students engaging in weekly career awareness using digital content and Virginia Career VIEW with robust modules and resources to explore careers in STEM and CS. These tools will support the process of developing portfolios of career awareness activities that inform Academic Career Plans to be completed in middle school. *Authentic assessment and exhibition of skills* will be provided through opportunities aligned to CS standards such as: student STEM competitions (Robotics, Destination Imagination, Vex Robotics, KidWind Challenge, Lego League Jr.), quarterly student showcases tied to CS performance-based assessments, quarterly family nights (hands-on activities to help promote foundational ideas), monthly EL Family nights, and semi-annual trips to our district's Innovation Center which is a cutting-edge facility adjacent to our high school that offers labs in information technology (i.e., computer science, cybersecurity). *Field trips and afterschool extensions* will target traditionally underrepresented students to encourage opportunities to spend space and time together with students like themselves while pursing CS interests.[28] For example, minority students will have the opportunity to visit Historically Black Colleges and Universities by touring Howard and

Hampton University's CS departments. Weekly, one-hour afterschool opportunities will include: CS Kids - an extension offering fun, hands-on activities for grades K-2 with one day for girls and one day for minority students and CS Clubs - activities for grades 3-4 with one day for girls (e.g., Girls Who Code) and one day for minority students. We will also study the effect of integrating CS units by expanding *hands-on learning in the summer* through five CS Camps: Four different full-day, week-long CS Camps with engaging CS activities serving the following groups: (1) girls grades 1-2; (2) minority students grades 1-2; (3) girls grades 3-4; and (4) minority students grades 3-4. (5) Our 4th graders will also have the opportunity to participate in STARBASE - a Department of Defense program that immerses students in a unique experience for five days where all activities are student-centered, hands-on, encourage higher order thinking, and incorporate CS and STEM applications in the real world.

◆**Contribution of Strategies:** The demonstration and amalgamation of these promising new strategies highlighted above will provide: (1) a model to integrate CS standards with instructional activities at the elementary level; (2) refined and tested rigorous CS elementary curriculum units connected across all subjects with a defined design process for other districts to develop units based on their needs; (3) student performance-based assessment system in CS for elementary schools; (4) a collection of teacher development trainings, curriculum design modules, and student real-world tethers to support instructional practice; (5) tools to expand access to and participation in rigorous CS coursework for traditionally underrepresented students, catching students in the early years before bias sets in; (6) validation of findings in relation to a broader range of students by reducing selection bias and student interest factors by intentionally placing low-income, minority students in a STEM-themed school focused on CS; and (7) data on the characteristics of integrated CS curriculum and instruction associated with positive engagement and achievement.

B. QUALITY OF THE PROJECT DESIGN

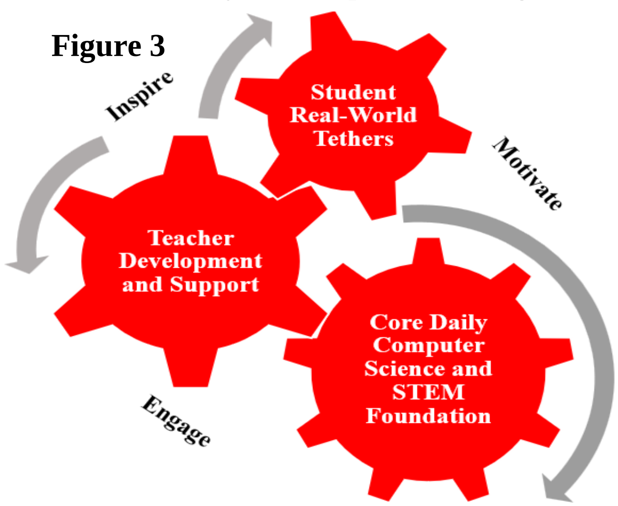
(1) Goals, Objectives, and Outcomes. Our goals, objectives, and outcomes are in Table 2.

Table 2. Metrics Goals and Objectives
Goal 1. Create and implement rigorous CS curriculum units
Objective 1.1 By the end of Year 2 and annually thereafter, develop and implement at least 5 problem-based learning, curriculum units per grade level focused on CS and computational thinking, integrated across all subjects that meet the Buck Institute PBL standards. **Measure:** School records and Buck Institute for Education PBL Project Design Rubric. [29]
Objective 1.2 By the end of Year 2 and annually thereafter create at least 5 performance-based assessments (PBAs) per grade level for the K-4 CS curriculum units that meet a "full evidence" quality rating. **Measure:** VA Quality Criteria Review Tool for Performance Assessments.[30]
Objective 1.3 For each CS unit, at least 75% of students will demonstrate mastery on associated PBAs. **Measure:** Project-developed PBAs that meet VA PBA standards (1.2 above).
Objective 1.4 Each year, at least 90% of K-4 students will participate in at least one CS-focused PEDLE activity per week. **Measure:** PEDLE lab participation logs.
Objective 1.5 Each year, at least 90% of K-4 students will participate in at least one CS-focused makerspace or STEM lab activity per week. **Measure:** Makerspace/STEM lab participation logs.
Objective 1.6 Increase by at least 5% annually the percentage of 3rd and 4th grade students who score proficient or advanced on the VA Standards of Learning (EOG) math test. **Measure:** VA Standards of Learning (EOG) math test. **Baseline:** John Kerr Elementary 3rd grade=64%, 4th grade=74%; Garland Quarles Elementary 3rd grade=70%, 4th grade=74%.
Objective 1.7 Increase by at least 5% annually the percentage of 3rd and 4th grade students who score proficient or advanced on the VA Standards of Learning (EOG) reading test. **Measure:** VA Standards of Learning (EOG) reading test. **Baseline:** John Kerr Elementary 3rd grade=69%, 4th grade=77%; Garland Quarles Elementary 3rd grade=70%, 4th grade=59%. [Please Note: Since science is not a standardized tested area K-4 and our project integrates CS across the curriculum, we have included an objective on reading proficiency.]
Objective 1.8 By the end of Year 1, at least 70% of students will indicate increased confidence in CS; increasing by 5 percentage points in Years 2-5. **Measure:** CS Attitude and Identity Survey[31] administered and reported bi-annually (reliability Cronbach's alpha=0.66; principal component analysis identified three distinct components, one of which is CS confidence).
Goal 2. Provide high-quality teacher development and support to sustain CS practice
Objective 2.1 Each year, at least 90% of K-4 teachers will receive a minimum of 60 hours of computational thinking/CS professional development (in-person, online, via PLCs, and through micro credentialing). **Measure:** PD attendance tracking log, compiled annually.
Objective 2.2 Each year, at least five teachers from each school will participate in at least one STEMersion experience. **Measure:** STEMersion participation logs.
Objective 2.3 Each year, at least 90% of teachers will receive at least four individual CS instruction coaching sessions. **Measure:** Quarterly coaching logs.
Objective 2.4 By the end of Year 2, the percentage of teachers who achieve a "proficient" rating on CS and computational thinking instructional strategies will increase by 10 percentage points over Year 1 baseline; increasing by 5 percentage points in each of Years 3-5 or until at least 90% of teachers achieve the "proficient" rating. **Measure:** Classroom observations using project-developed rubric based on International Society Technology Education Standards for CS Educators[32] completed by CS coaches, assessed quarterly. **Baseline:** Year 1.

Table 2. Metrics Goals and Objectives
Goal 3. Strengthen student tethers to CS and STEM coursework via real world linkages
Objective 3.1 Each year, at least 75% of students in each grade will attend at least two CS-focused field trips that align to VA CS learning standards. **Measure:** Field trip attendance logs.
Objective 3.2 By Year 2, increase the percentage of students who report interest in STEM fields by 5 percentage points over baseline, increasing 5 percentage points in each of Years 3-5. **Measure:** Student Attitudes Toward STEM Survey[33] (reliability Cronbach's alpha ranges 0.83 to 0.92, validity established by subject matter expert). **Baseline:** Year 1.
Objective 3.3 By Year 2, increase the percentage of racial/ethnic minority students who report interest in STEM fields by 5 percentage points over baseline, increasing 5 percentage points in each of Years 3-5. **Measure:** Student Attitudes Toward STEM Survey (reliability Cronbach's alpha ranges 0.83 to 0.92, validity established by subject matter expert).[34] **Baseline:** Y1
Objective 3.4 By Year 2, increase the percentage of female students who report interest in STEM fields by 5 percentage points over baseline, increasing 5 percentage points in each of Years 3-5. **Measure:** Student Attitudes Toward STEM Survey[35] (reliability Cronbach's alpha ranges 0.83 to 0.92, validity established by subject matter expert). **Baseline:** Year 1.
Objective 3.5 Each year, students in grades K-2 who participate in CS Kids afterschool activities and students in grades 3-4 who participate in CS Clubs will attend at least 80% of all sessions. **Measure:** CS Kids and CS Club attendance logs.
Objective 3.6 Of the students participating in summer learning extensions, at least 80% will be from underrepresented groups including minorities and females. **Measure:** Summer records.
Objective 3.7 Each year, at least 80% of students in each grade will participate in at least two CS-focused activities at the Innovation Center. **Measure:** Innovation Center attendance logs.

(2) Conceptual Framework. Through **Metrics**, we will study of the impact of field-initiated innovations in CS focused on K-4 elementary students in two STEM-themed schools. Our *theory of action* is that a whole school immersion approach to CS integrated across the curriculum into daily classroom and real-world experiences will boost traditionally underrepresented, high-need student aspirations, attainment, and achievement. Our conceptual framework includes three core components illustrated in *Figure 3* and is presented in detail in our logic model in *Appendix G* (**Absolute Priority 1**). Rather than taking a siloed approach focusing on one component, we hypothesize that the

Figure 3



creation of an elementary school continuum, with CS across the curriculum and the interaction and additive effect of all three components working together, will have a positive impact on improving achievement and attainment for high-need, traditionally underrepresented students. Predicted outcomes include increases and improvements in the following: student interest, knowledge, and skills in CS and computational thinking (Core Daily CS Foundation); teacher knowledge and instructional skills in CS and STEM (Teacher Development and Support); and engagement in CS for traditionally underrepresented students and student interest and aspirations in CS careers (Student Real-World Tethers). Ultimately, we predict the results of our study will show three key impacts: (1) improved academic achievement in math and reading for high-need K-4 students **(Absolute Priority 3)**; (2) students prepared for success in CS focused curriculum and activities in middle and high school; and (3) expanded access to and participation in rigorous CS coursework for traditionally underrepresented students which includes learning in areas such as computing principles, algorithmic processes, computational thinking, coding, analytics, and computer programming **(Competitive Preference Priority)**. The following highlights research and model practices that support our conceptual framework: (1) There are several key components known to make CS fundamental in an education system which include:[36] defining CS and establishing rigorous CS standards, allocating funding for CS teacher professional learning, and establishing dedicated CS positions in districts. The **Metrics** framework is designed with these three fundamentals through: the development of rigorous CS curriculum units linked to standards that support STEM coursework connected across all subjects through problem-based learning; a high-quality teacher development and support process to sustain innovative CS instructional practices; and the provision of three, full-time CS Integration Specialists. (2) Another model practice is using funding for high-quality professional learning that trains the existing teaching workforce rather than hiring new CS teachers which improves implementation rates.[37] Our teacher development and support process is centered on training all K-4 teachers to support a whole school immersion approach through strategies such as coaching, coteaching, PLCs, micro-credentialing, and STEMersion. To build capacity and sustainability and institute a train-the-trainer approach, our framework incorporates one existing teacher from each grade level (5 per school) to serve as a CS Coach. (3) The need to engage younger students in CS before high school is recognized as a crucial practice to reach students, especially traditionally underrepresented students, before they are predisposed by negative cultural stereotypes or lose interest.[38] Exposure to standards that are high-quality and equitable form foundational perceptions for all students as opposed to only students who typically show interest in CS.[39] Our framework recognizes that early exposure to CS and STEM in elementary school is critical which influences future interest and career aspirations. Through **Metrics**, our strategies impact K-4 students and reduce selection bias and student interest factors by intentionally placing low-income, minority students in STEM elementary schools located in their attendance zone. (4) The development of skills in CS and computational thinking are as fundamental to education as reading, writing, math, and science.[40] A key practice is the amalgamation of these skills across all disciplines with lesson designs that integrate CS and computational thinking, enabling students to gauge information, break down a problem, and generate a solution through the use of data and logic.[41] Through **Metrics**, a whole school immersion approach to these skills is integrated across the curriculum into daily classroom and real-world experiences using problem-based learning and making CS and computational thinking fundamental to other core subjects. To ensure rigor, each unit requires problem solving, critical thinking, collaboration, and a variety of communication methods and incorporates the following elements shown to lead to project success: a challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and public product.[42] (5) A best practice recognized by the National Science and Technology Council is the creation of STEM ecosystems which engage educators and students within and outside formal education environments by forming shared and sustainable STEM missions that bridge learning opportunities.[43] Ecosystems foster high-quality partnerships among educators, organizations, and industries that bring in real-world experiences and challenges and increase student interests in STEM and CS careers, helping students see themselves as future practitioners. Research finds that when these levers in an ecosystem are activated, students' STEM achievement and aspirations are enhanced significantly.[44] **Metrics** is designed with a core component of student real-world tethers which creates this type of ecosystem through extensions such as co-development of curricula, career exploration field trips, and hands-on summer learning experiences for teachers through STEMersion. We have a variety of partners (e.g., Shenandoah University, Shenandoah Valley Discovery Museum, Museum of the Shenandoah Valley, STEM businesses) which help fuel this ecosystem highlighted in *Appendix C*.

(3) Feedback and Continuous Improvement. To ensure feedback and continuous improvement in project operations, we will use the following procedures. ◆**Procedure 1: Management Structures:** The *Management Team* will meet monthly, provide overall project direction, and work closely with the principals at each target school and include: the district Superintendent, Project Director, Director of Elementary Education, Director of Secondary Education, and District Math Specialist. Meeting quarterly, the *Advisory Council* will review implementation data to determine if adjustments are needed and make recommendations to each school team and includes the Project Director, ESOL Coordinator, CS Integration Specialists, principals, and partners. Meeting weekly, *school teams* will include the CS Integration Specialists, lead CS Coach for each grade level, STEM Teacher, and the PEDLE Lab Coordinator. This team will bring feedback from teachers and pinpoint areas of improvement to ensure enhancements in operations at each school. Both school teams will meet quarterly to share best practices and address implementation issues. ◆**Procedure 2: Plan-Do-Study-Act (PDSA):** Our district has implemented the PDSA best practice to monitor implementation of new strategies and initiatives which will be used by our management structures to refine our project. PDSA is based on a continuous sequence of four action steps to plan a change with the goal of improvement (Plan), test the change on a small scale (Do), analyze the results (Study), and once complete, make adjustments and either adopt, abandon, or complete the PDSA cycle for a second time until improvements are no longer needed (Act).[45] ◆**Procedure 3: Evaluation:** A participatory approach to evaluation will ensure that data is strategically used on a regular basis to provide feedback to refine implementation and make programmatic changes as needed. Through continuous monitoring, the evaluation team will provide periodic feedback to each school and will triangulate the data to provide a synthesis of project-wide, evidence-based data. Results will be shared using interim and annual performance reports, infographics, data snapshots, consultation, and survey reports of parents, students, and teachers. ◆**Procedure 4: Logic Model:** The **Metrics** logic model in *Appendix G* ensures that both continuous quality improvement and project enhancement are guided by evaluation. The model has a built-in feedback loop to provide timely and useful information to stakeholders for informed decision-making relative to needed changes in program activities. Short-term performance indicators will be used to assess progress toward long-term outcomes. Annual benchmarks are established and embedded in our outcomes and will be used to graphically chart actual progress against targeted progress. ◆**Procedure 5: Students with Special Needs:** To ensure feedback and solid operations for all students, the Project Director will take the lead in assuring resources are available for all students to participate. For example, the Project Director will collaborate with the ESOL Coordinator to ensure that students have access to ESOL teachers (and translators at events) for language development across content areas that may otherwise prevent participation. The Project Director will collaborate with the Special Education Director to ensure that students with disabilities have access to specialized equipment so as not to hinder participation.

C. ADEQUACY OF RESOURCES AND QUALITY OF MANAGEMENT PLAN

(1) Management Plan. Serving as the EIR Project Advisor (PA), our Superintendent will oversee the *Management Team* (MGT) that will include the **Metrics** Project Director (PD), Director of

Elementary Education, Director of Secondary Education, and District Math Specialist. This team will provide project direction, operations management, fidelity of implementation, and fiscal accountability. The *Project Director* will lead day-to-day operations of **Metrics**, collaborate with partners and evaluators, lead professional development, and ensure that students across disabilities and backgrounds can fully participate. An initial *Core Team* of K-4 teachers and staff will examine the standards and design a plan on how to integrate CS standards and performance-based assessments across the curriculum and standards of learning as well as assess digital tools to support learning. Management of grant activities will also be supported by the *Advisory Council* (**Metrics** staff, principals, ESOL Coordinator, partners) and *school teams* (CS Integration Specialists, lead CS Coaches, IT Resource Teacher, two STEM teachers, and PEDLE Lab Coordinator). An *independent evaluation firm*, The Evaluation Group, will conduct an impact study that meets WWC standards with reservations and a fidelity of implementation study as described in Section D. Table 3 presents timelines and milestones for completion of major project activities for each goal area. Specific, well-defined project objectives and annual performance targets to monitor goal attainment were previously highlighted in Table 2 above.

Table 3. Metrics Management Plan (October 1, 2019 – September 30, 2024)		
Milestones	**Timeline**	**Responsibility**
Overarching Project Management and Activities		
Convene Management Team	Begin 10/19, monthly	PA
Confirm partner commitments	10/19	MGT
Hire grant staff	10/19-12/19	MGT
Identify Core Team members	11/19	PA
Conduct evaluation (data collection/analysis/tools)	Begin 11/19, quarterly	Evaluator
Convene Advisory Council	Begin 1/20, quarterly	PD
Implement ongoing sustainability planning for support after Federal funding ends	Begin 5/20, quarterly 9/23, plan finalized	Advisory Council
Goal 1: Create rigorous CS curriculum units to support STEM coursework		

Objectives: 1.1 CS PBL Units, 1.2-1.3 CS Performance-Based Assessments, 1.4 CS PEDLE Lab, 1.5 Makerspaces or STEM Labs, 1.6-1.7 VA EOGs, 1.8 Student CS Confidence		
Develop and refine plan for CS units (Phase 1)	11/19-2/20	Core Team
Pilot curriculum plan with teacher group (Phase 2)	3/20-6/20	Core Team
Revise plan based on teacher feedback (Phase 2)	6/20-8/20	Core Team
Introduce revised plan to stakeholders (Phase 2)	8/20	CS Specialists
Convene school teams (Phase 3)	Begin 9/20, weekly	CS Specialists
Implement plan into instruction (Phase 3)	Begin 10/20, ongoing	Teachers
Review units for fidelity (Phase 3)	Begin 10/20, monthly	School Teams
Develop performance-based assessments (Phase 3)	10/20-12/20	School Teams
Convene joint school team meetings (Phase 4)	Begin 11/20, quarterly	CS Specialists
Integrate instructional supports: digital tools (daily), makerspaces (weekly), STEM lab (weekly), and PEDLE lab (at least weekly) (Phase 4)	Begin 11/20, weekly	School Teams Teachers
Continue to implement/refine units/PBA (Phase 5)	Begin 1/21, ongoing	Teachers
Goal 2: Develop a high-quality teacher development and support process to sustain CS		
Objectives: 2.1 Training Hours, 2.2 STEMersion, 2.3 Coaching, 2.4 CS Strategies		
Create professional development schedule	Begin 1/20, annually	PD
Support Core Team in CS curriculum unit design	Begin 1/20, monthly	CS Specialists
Design PLCs with CS and interdisciplinary focus	Begin 1/20, ongoing	CS Specialists
Offer innovation conference to support roll out	1/20	PD
Confirm CS Coaches for each grade level	Begin 2/20, annually	PD
Use PLCs to refine CS units and instruction	Begin 3/20, weekly	Coaches
Support PLCs in implementation of CS plan	Begin 3/20, weekly	CS Specialists
Provide in-class coaching and modeling	Begin 3/20, weekly	CS Specialists
Coordinate district technology training days	Begin 4/20, annually	PD
Host teacher innovation showcase for district	Begin 4/20, annually	PD
Provide 2-day summer institutes	Begin 6/20, annually	PD
Implement 5-day STEMersion experience	Begin 7/20, annually	Partners
Goal 3: Strengthen students' tethers to CS coursework by engaging in real-world linkages		
Objectives: 3.1 Field Trips, 3.2-3.4 Interest, 3.5-3.6 Afterschool/Summer, 3.7 Innovation Center		
Develop and confirm community partnerships	Begin 1/20, ongoing	PD

Engage students via career awareness activities	Begin 1/20, weekly	Teachers
Schedule and implement industry field trips	Begin 1/20,semi-annually	PD, Partners
Design vertical alignment of STEM to field trips	Begin 1/20, ongoing	Coaches
Schedule career days and guest speakers	Begin 1/20, quarterly	PD, Partners
Implement CS Kids and CS Clubs	Begin 2/20, weekly	PD, Partners
Organize and hold STEM competitions	Begin 3/20, monthly	PD, Teachers
Organize and hold student innovation showcases	Begin 4/20, quarterly	PD, Teachers
Offer family/EL nights to promote CS foundations	Begin 4/20, quarterly	PD, Teachers
Implement hands-on activities at Innovation Center	Begin 4/20, quarterly	PD, Teachers
Provide hands-on summer learning camps	Begin 7/20, annually	PD, Teachers
Use STEMersion training to integrate curricula	Begin 9/20, ongoing	Teachers

(2) Qualifications of Key Personnel. The following highlights the qualifications of key personnel with detailed resumes and job descriptions in *Appendix B*: (1) The Superintendent and *Metrics Project Advisor*, Dr. Jason Van Heukelum, has a Ph.D. in Education with extensive experience managing successful large-scale federal awards including over $10 million in U.S. Department of Education's Investing in Innovation and School Climate Transformation Grants in a prior district and serving as an adjunct professor with the School of Education at UNC Chapel Hill. (2) The Director of Elementary Education and *Metrics Management Team* member, Jacob Boula, earned a M.S.A. in Curriculum and Instruction and has served over 15 years as a teacher, personalized and gifted learning coordinator, and principal with "distinguished" ratings on yearly evaluations. (3) Providing continuity of efforts into middle school, the Director of Secondary Education and *Metrics Management Team* member, Brian Wray, earned a M.Ed. in Educational Leadership and has served nearly 20 years as a teacher, program coordinator, principal, and director of instruction for all grade levels. (4) The District Math Specialist and *Metrics Management Team* member, Kristin Nicholson, earned a M.A. in teaching PK-6, Algebra I and middle school math as well as postgraduate certificates in Education and Administration and Math Specialist K-8 and has served 10 years as a math teacher, instructional math K-4 specialist, and district PK-12 math specialist.

(5) A Master's level *Metrics Project Director* will have at least five years of relevant experience in: CS, STEM, and problem-based learning; providing program oversight, leadership, and fiscal accountability in an educational setting; leading professional development; and collaborating with stakeholders and partners. (6) Three master's level *Metrics CS Integration Specialists* will have at least four years of relevant experience in CS, STEM, and problem-based learning in: a classroom setting at the elementary level; teacher development and coaching; and development of curricula units, instructional sequences, and performance-based assessments. (7) Britt Miller, *PEDLE Lab Coordinator*, has a M.A. in Teaching with an English to Speakers of Other Languages endorsement and has served as an elementary and ESL teacher and a personalized and digital learning specialist. (8) Kim Peterson, *ESOL Coordinator*, has a M.A. in Education with certification in ESL and over 16 years' experience in working with EL families serving as a champion for ESL students. (9) *The Evaluation Group,* a firm with over 30 years of experience, including ten i3/EIR evaluations, was identified through a competitive procurement process. The lead evaluators, Dr. Kathleen Dowell and Christy Derrick, MPH, are experienced in designing, conducting, and managing partner-focused, participatory evaluations in a wide variety of areas including education and STEM.

(3) Potential for Continued Support. The commitment from our district, administrators, teachers, and community partners are critical to long-term success of **Metrics**. This commitment is already evidenced by the district's existing implementation of STEM reform efforts which will be enhanced by the addition of a CS focus and includes: (1) transforming STEM education with CS to a district priority area; (2) developing a K-4 continuum beginning with the design of two complete STEM elementary schools so that every student in the school's attendance zone is reached; (3) designing high-quality STEM and PEDLE labs at each school to provide hands-on, personalized learning; (4) employing PLCs and other instructional supports to design and implement problem-based learning units; and (5) advancing STEM and CS efforts beyond elementary school through a cutting-edge Innovation Center at the high school which is a publicprivate partnership that ensures students are empowered with a marketable skill that provides regional industries with skilled workers. The EIR Advisory Council will engage in a sustainability planning process beginning in Year 1 and produce a sustainability plan by the end of Year 4 to ensure continued support after Federal funding has ended. This plan will address existing capacity using evaluation results to clarify programmatic elements that should be preserved with an emphasis on leveraging district and community resources. There are several components that will sustain naturally through **Metrics**. For example, professional development will produce 10 grade level CS Coaches who are existing teachers at our target schools and will employ a train-the-trainer approach to ensure innovative practices continue. Further, through our training efforts, PLCs will remain, and trained teachers will continue to refine and develop rigorous CS curriculum units to support STEM coursework connected across all subjects. *Appendix C* documents the commitment of our district and partners to **Metrics** as well as potential support of successful components after Federal funding ends. This support includes Memorandum of Understandings demonstrating the commitment of our district administrators, principals, and STEM industry partners. We have partners providing a financial match or specific contributions documented in *Appendix C & H:* WPS School Board, CodeVA, Shenandoah University, Bright Futures, Handley Trust, Museum of the Shenandoah Valley, Shenandoah Valley Discovery Museum, and STARBASE.

D. QUALITY OF PROJECT EVALUATION

(1) WWC Standards with Reservations. The Evaluation Group will conduct a formative evaluation to support the development and refinement of **Metrics** components, assess the quality and fidelity of implementation, and engage in evaluation activities that will address key research questions about the impact of the project on student outcomes. Our confirmatory impact study will test the effectiveness of the project on student achievement and will answer the question: What is the impact of **Metrics** on the academic achievement of students in grades 3-4 after three years of programming? The study will occur during Years 1-5 and will use a quasi-experimental comparative short interrupted time series (CSITS) design that will meet What Works Clearinghouse (WWC) 4.0 evidence standards with reservations[46]. The CSITS design has been shown to provide internally valid estimates of the impact of school-level interventions by comparing outcomes of students at treatment schools to outcomes of students attending schools that do not adopt an intervention.[47] In this case, the "interruption" is the implementation of the project starting in Year 1. We will use five years of pre-intervention achievement data (2015-19) and five years of post-intervention (2020-24) data to compare students in two WPS elementary schools that implement **Metrics** to 10 comparison elementary schools (two schools within WPS and eight schools in other VA districts) that do not implement the program. Comparison schools that are similar in baseline achievement and demographics will be selected using a 1:5 nearest neighbor propensity score matching model (PSM) without replacement. This model is designed to increase generalizability to other VA schools and will include key variables, such as baseline test scores, free and reduced lunch rate, percent minority students, and gender. Academic achievement in math and reading will be measured using the VA Standards of Learning (EOG) exams. We will use school-level mean standard scores on VA EOG tests in math and reading from multiple pre-intervention years (2015-19) to test baseline equivalence of the treatment and comparison schools. Data from the grade-level cohorts will be pooled and compared at the end of 2023-24 after the program has been fully implemented for five years. Little to no school attrition is anticipated as we are collecting publicly available data. Outcome data for the CSITS will be analyzed using a three-level model with repeated observations over time (level 1) on grades (level 2) nested in schools (level 3). Effect sizes will be computed. Table 4 specifies the study parameters.

Table 4. Summary of Design Parameters for Confirmatory Study	
Parameters	**CSITS for Academic Achievement**
School Level	Elementary (grades 3-4)
Unit of Analysis	Grades nested in schools
Sample Size	12 schools (2 **Metrics** schools, 10 comparison schools,

Table 4. Summary of Design Parameters for Confirmatory Study	
Parameters	**CSITS for Academic Achievement**
	little to no expected attrition)
Confirmatory Outcome(s)	Academic achievement in grades 3-4; measures: VA Standards of Learning (EOG) math and reading tests
Propensity Score Matching Covariates	Baseline VA Standards of Learning (EOG) reading and math scores, % of students receiving free- or reduced-lunch, % of students who are minorities, % female students
Statistical Analysis	Three-level HLM model with repeated observations over years (level 1) with multiple grades (level 2) nested in schools (level 3)
MDES	0.66 (alpha .05, power .80, *Appendix I*)
Model	$Y_{ij} = \beta_0 + \beta_1 Treatment_k + \beta_2 TreatmentYear_{ik} + \beta_3 Treatment_k TreatmentYear_{ik} + \beta_4 BaselineScore_{jk} + \beta_5 FreeReducedLunch_k + \beta_6 MinorityStatus_{jk} + \beta_7 Gender_{jk} + \beta_8 Cohort_k + \beta_9 Grade_{jk} + \mu_j^{schools} + r_{jk}^{Grades} + \epsilon_{ijk}^{Years}$

We will also conduct exploratory studies, examining the impact on academic achievement and CS attitudes among female students, academic achievement and CS attitudes among underrepresented minority students, and 5th grade science scores, by gender and minority status.

(2) Guidance about Replication. In Years 1-5, we will conduct an implementation study to guide the replication of this project in other districts. The implementation study will answer the questions: (1) To what extent are schools implementing with fidelity? (2) What project components are most effective at achieving desired outcomes and suitable for replication? and (3) What factors facilitate implementation and what key challenges need to be addressed to guide replication? We will collect implementation data from multiple sources – classroom observations, teacher surveys, professional development logs, and teacher interviews and focus groups – to identify factors and challenges affecting implementation. A fidelity index (*Appendix I*) will be developed with indicators that align with the project components and strategies identified in our logic model (i.e., PD, CS units) and minimum thresholds for implementation (i.e., teacher hours of PD participation, number of CS units implemented per classroom). Fidelity data will allow us to document, track, and assess the extent to which actual implementation aligns with proposed implementation. For each component, fidelity scores will be computed based on student-, teacher- and/or school-level indicators of adherence (i.e., number of teacher professional development hours), exposure (i.e., number of CS units implemented), quality (i.e., number of teachers who use the essential elements of problem-based learning in their classrooms daily), and responsiveness (i.e., number of students who report increased engagement) to give us a comprehensive assessment of the implementation of **Metrics**.[48] Component fidelity scores will be summed to compute an overall fidelity index. Targets will be established a priori for each indicator using baseline data, scaling targets, and input from subject-area experts. Our evaluator will report progress toward targets semi-annually to support continuous, iterative program improvements. To the extent data are available, we will collect fidelity data on comparison schools and students as well to determine the "achieved relative strength" of **Metrics** in comparison to the non-targeted schools.[49] To identify the components that have the greatest impact on outcomes, we will run regression models, with component fidelity scores as independent variables and student outcomes (i.e., achievement) as dependent variables. Results of these analyses will inform other LEAs about which components are most critical for replication and have the greatest impact on student outcomes. In the last year of the grant, we will finalize the CS units, assessments, and PD guides for other districts to replicate our project.

(3) Valid and Reliable Data. Our evaluation will use a mixed-methods approach that combines qualitative and quantitative data to provide a comprehensive set of data on project implementation and effectiveness. Quantitative data include: VA Standards of Learning (EOG) (assumed to have face validity and be reliable[50]), professional development attendance, teacher surveys, Buck Institute PBL Project Design Rubric,[51] VA Quality Criteria Review Tool for Performance Assessments, PBAs,[52] the CS Attitude and Identity Survey[53] (reliability Cronbach's alpha=0.66; principal component analysis identified three distinct components), the S-STEM Survey[54] (reliability Cronbach's alpha ranges 0.83 to 0.92, validity established by subject matter expert review and cognitive interviews with students), and classroom observations guided by a project-developed rubric based on International Society Technology Education Standards for CS Educators.[55] During Years 1-2, we will calculate internal consistency of survey scales by calculating Cronbach's alpha and refining survey items until alpha exceeds 0.70. Qualitative data include teacher interviews and focus groups, student focus groups, and open-ended teacher and student survey questions. Qualitative analysis will be guided by code development,[56] scholarly literature, stakeholder panels,[57] and member checking[58] and will provide depth and context to the quantitative data. The constant comparative method will be used to increase the trustworthiness of results. Each qualitative data collection process will stop when we reach saturation.[59]

(4) Evaluation Plan. The **Metrics** logic model shows key components (CS units, professional development, real-world tethers), mediators (teacher knowledge and practices, student engagement), and outcomes (student achievement and attitudes). Quarterly review of the logic model and progress on our goals and objectives will allow us to continually gauge progress and identify needed program changes. Our goals and objectives, in tandem with our logic model, articulate the key components of our program and the measurable thresholds for acceptable implementation as outlined in Table 2. Our evaluation plan details the data collection tools and timelines, measures, methods of analysis, and reporting schedule as specified throughout this proposal. Together, the logic model, performance measures, fidelity data, and outcome data will help us determine the extent to which **Metrics** is effective at increasing student achievement and improving students' attitudes toward CS. Results will be shared using interim and annual performance reports; reports of student and teacher surveys and focus groups; infographics; data snapshots; and in-person presentations. Monthly check-ins with the project team will ensure that all team members are up-to-date on progress. Through **Metrics**, we will implement and test our theory that a whole school immersion approach to CS integrated across the curriculum into daily classroom and real-world experiences will boost traditionally underrepresented, high-need student aspirations, attainment, and achievement and serve as a national CS model for replication.