Table of Contents

A. Significance

Project {FUTURE} will engage elementary teachers in Connecticut and Wisconsin in progressive and sustained professional development in computer science education to positively impact student outcomes in computer science (CS) and other identified areas. We propose Project: {FUTURE} - FUndamentals Teacher Unit-based Research Exemplars, the culminating output of which will be the development, testing and dissemination of teacher-created exemplar units integrating the concepts of *Computer Science Fundamentals* (Code.org (a), 2019) into other content areas. By building capacity and setting models, Project {FUTURE} can set a course for elementary CS, a critical venture for the future of our nation, our schools, and our students.

A.1 National Significance Computer science is the {FUTURE}. Increasing the supply of workers with CS skills in the U.S. is a fundamental requirement for building a high skill / high income 21st-century workforce (National Research Council, 2010). Demand for workers with CS skills significantly exceeds the supply of such workers. Growth areas include both traditional application areas such business computing or data communications and new application areas such as modern manufacturing (Dwyer, 2012), biotechnology, medicine, finance and entertainment. Computing applications are ubiquitous in industry and government, as is the need for skilled CS workers. Addressing the current need for highly-skilled CS workers will allow the United States economy to maintain its current high-tech industries.

A.2 Persistent Barriers – CS Careers In spite of increasing demand, the number of students pursuing post-secondary degrees that develop CS skills, and lead to CS jobs, lags well behind demand. Three significant factors have been shown to influence student selection of a computing-centric field in college. First, the amount and quality of CS instruction at the primary and secondary education levels (grades K-12) has not kept pace with other disciplinary areas

(Computer Science Teachers Association, 2015). Computing resources are more commonly used as tools of instruction or to teach basic information technology literacy skills rather than to teach CS concepts. CS learning experiences in schools often fail to convey that it is an inherently creative activity in which we design and build computing artifacts that affect the ways we interact with and learn about the world.

The second factor is that students, their parents, counselors, and often their teachers, have very limited information regarding the types of careers available to someone with specialized education in CS. Courses labeled “computer literacy” or “technology” often emphasize rote knowledge and application, rather than key, higher-level thinking skills, which are important even at the elementary level. Paradoxically, while school curricula may strive to make CS an appealing area of future study or work, the way computers are actually used in school may discourage students from pursuing CS-related courses of study and careers.

The third factor is that given the relative lack of diversity in the current CS workforce and teaching community (Payton, 2003), students from traditionally underrepresented groups lack role models with whom they identify and may come to think CS is not an appropriate career path for them. The changing racial demographics of the United States require outreach from the CS community to historically underrepresented groups. Researchers warn of a “virtual segregation” (Margolis, 2017), perpetuating and feeding a cycle that prevents underrepresented minorities (URM) in large urban districts from even having the opportunity to be exposed to “privileged knowledge” (Wilson, Sudol, Stephenson, & Stehlik, 2010) -- actual computer science -- during their education careers. The national trends are mirrored in Wisconsin and Connecticut. Using AP scores as K-12 endpoints, while URM comprise 35% of the student population in CT, they were only 15% of AP CS exams (Code.org (b), 2019). While URM comprise 31% of the student population in WI, they were only 13% of AP CS exams (Code.org (c), 2019). Overcoming these problems requires collaboration among many stakeholders, including teachers, higher education CS faculty, teacher educators and educational researchers, K-12 school boards and administrators, and industry (Chang, 2009).

A.3 Opportunity for Elementary CS Elementary students are the {FUTURE}. The pipeline of computer science career interest needs custodians all along the way. We propose that elementary schools are an underutilized resource for promoting broad access to assured experiences in CS, sparking interest, building foundational skills and dispositions, and establishing programmatic cohesion across the K-16 trajectory. These early experiences are especially critical as students face the impending "middle school cliff" (Jones, 2017) a dramatic loss of interest in CS. In the short term, CS instruction teaches valuable skills and dispositions like problem-solving, collaboration, critical thinking, persistence, and growth-mindset. These skills are associated with a high-quality education in the 21st century (Batelle for Kids, 2019; Dweck, 2006). By situating our proposed project in predominantly high-needs schools (as we are defining based on the significant population of underrepresented minorities (URM) and low socio-economic status via Free and Reduced Meals rate) the proposed project will address the opportunity gap that currently exists in CS education and help to expand access and participation in rigorous computer science coursework in high-need communities.

A.4 Building on Existing Strategies - Code.org In the proposed project, we build on existing strategies to provide a progressively and sustained professional learning model, leading to the development of CS-embedded curriculum unit exemplars as described in the Logic Model. We build on the professional learning program developed by national nonprofit Code.org, the leading provider of K-12 CS curricula. Specifically, their introductory elementary teacher workshop *CS Fundamentals* has been attended by over 20,000 teacher participants in the four years since its launch. After thousands of teacher satisfaction survey results, the workshop program is now in its fourth revision. Developed with substantial private funding, largely from the technology sector, workshop participants have consistently provided enthusiastic reviews, with the majority of participants agreeing that it is "the best professional development I've ever attended," and an overall rating of 4.8 out of 5 (Code.org (d), 2019). Sacred Heart University and Marquette University are Code.org's Regional Partners in CT and WI, respectively, hosting teacher workshops and joining CS outreach - advocacy efforts.

While Code.org monitors workshop survey results (Appendix I.1) and platform activity, its ability to further probe or follow up with participants is minimal. As a result, though we know teachers are very satisfied with the workshop experience, it is not known what aspects of teacher beliefs and attitudes about computer science may have shifted or what factors affect how the Code.org workshop experience translates into action in the school setting. This limits efforts to study or compare effectiveness or generalize for sustainability. In addition, evidence-based guidance indicates that a one-day workshop is not the best model for professional learning (Darling-Hammond, Hyler, & Gardner, 2017). Project {FUTURE} introduces additional supports through school-embedded coaching of professional learning communities (PLCs). In addition to extending and embedding, these additional supports also allow the professional learning to be responsive to the needs of the school context, which is a characteristic of an effective school-university partnership (Author, 2018). Mutually beneficial partnerships between educator preparation providers and PK-12 can successfully create laboratories of practice for both university researchers and practicing teachers, providing continuous improvement for all involved. Such laboratories of practice emphasize classroom-ready innovations which have the potential to positively impact student learning and generate pedagogical and curricular innovations. With a design reliant on teacher-led CS curriculum innovation, subsequent field testing and teacher action research, the proposed project meets Absolute Priority #3 Field-Initiated Innovations- STEM, with focus on CS.

A.5 Anticipated Barriers and Challenges While studies of elementary computer science education are minimal, we anticipate a cross-over effect of many known barriers and challenges. First, we expect that unless otherwise intervened, elementary educators will hold many of the same limited and limiting beliefs and attitudes about CS and CS careers as the general population. In terms of their teaching readiness, based on national trends in course availability and historical graduation and certification requirements, we reason that today's elementary classroom teachers have, on average, even less previous exposure to CS or CS pedagogy than they do in science, an area of many well-documented barriers and challenges. Here we draw in particular upon decades of studies of science education which have found that elementary teachers generally lack background, experience and confidence in teaching science (Greenwood & Scribner-MacLean, 1997; Tilgner, 1990), cite challenges finding instructional time and professional development (Abell & Roth, 1992), and marginalize science because of competing priorities resulting from high-stakes testing (Center on Educational Policy, 2008; Crocco & Costigan, 2007). In the absence of strong expectations to teach science from their administrators, teacher motivation for science teaching is a significant mediator of student access to the target content (Berg, 2012; Ronan, 2014). Self-efficacy (Bandura, 1997), the belief an individual may or may not have that she can enact a desired performance, has been measured extensively in elementary science teaching and has been linked with motivation for science teaching (Ramey-Gassert, Shroyer, & Staver, 1996). As such, we expect elementary teachers to hold limiting beliefs about their own ability to teach CS. An exploratory study of CS implementation at the high school level (Outlier Research & Evaluation, 2017) highlighted self-efficacy for CS teaching as a measurement area of interest. The design of the *Research & Analysis Thread* of Project {FUTURE} builds on established theoretical and methodological foundations of STEM in elementary schools, as summarized in Table 1.

Table 1: Theoretical and Methodological Foundations of Project {FUTURE}

Research Gap for Elementary CS Education	Theoretical Framework (Foundational Work)	Measures / Methods
What shifts in beliefs and attitudes do elementary teachers experience with participation in a CS workshop?	Self-Efficacy (Bandura, 1997)	Teacher attitude and beliefs instrument to probe self-efficacy and beliefs about CS/CS teaching; semi-structured interviews and focus groups
What teacher and school context variables affect the development of teacher attitudes/beliefs as well as fidelity of implementation?	School contexts- Hierarchy and i-meanings (Carlone & Webb, 2006)	Rich field observation, interviews, member checking; classroom observation protocol
Do enhanced professional learning supports foster the development of computer science attitudes and beliefs, program implementation, and computer science pedagogy?	Communities of Practice (Lave & Wenger, 1998)	Teacher attitude and beliefs instrument to probe self-efficacy and beliefs about CS/CS teaching; semi-structured interviews and focus groups
Can the integration of CS into elementary curriculum units enhance CS skills and positively affect other identified student outcomes?	Epistemic Communities (Haas, 1992) Action Research (Cochran-Smith & Lytle, 1993)	Rich field observation, interviews, member checking during PLC-based unit development process Mentored teacher action research

A.6 Possibilities for Curricular Integration Curriculum integration is the {FUTURE}. As computer science becomes more familiar to elementary teachers, the potential for connections with other content areas can be explored. CS instruction has also shown the potential to positively impact elementary student outcomes in literacy, mathematics, and science (Century, Ferris, & Zuo, 2019). There is much skill overlap, for example, between *debugging* a computer program and closely reading a text. While dedicated “specials” and enrichment activities are a desirable form of early adoption, curriculum integration is critical to the eventual sustainability of CS instruction and the positioning of CS skills as fundamental for the modern age.

The proposed study also builds on the curriculum integration work of Project GUTS: Growing Up Thinking Scientifically, a program integrating computer science with science content (Malyn-Smith, Coulter, Denner, Lee, Stiles & Werner, 2010) to involve middle school students in the "design, creation, use, and analysis of computational models to study complex systems" (p. 3480) and a similar program, CS4HS for high school teachers (Bort & Brylow, 2013). While there are many high-quality digital tools in the content areas, especially science, the computer programming has generally been completed by the developers and hidden from view, positioning the students are "users" of the tool. Akin to tools of GUTS and CS4HS but adapted for the elementary level, the proposed exemplar units would contain activities which allow the students to tinker with the underlying programming on a supported, developmentally appropriate platform, positioning the students as "makers" and significantly enhancing both the level of computational thinking and content mastery required to engage with the task.

Drawing from a pedagogy for elementary computer science instruction brought to scale by Code.org, these plugged activities will be accompanied and supported by unplugged learning activities. In unplugged activities, students engage with the skills, principles, vocabulary, and dispositions of CS in developmentally appropriate activities which do not involve personal devices. They are "intentionally-placed kinesthetic opportunities that help students digest complicated concepts in ways that relate to their own lives" (CS Fundamentals, 2018). The proposed project applies this pedagogy to CS-embedded units in other content areas. By implementing and evaluating the impact of teacher-developed CS-embedded curriculum unit exemplars in high-needs schools, the proposed project is explicitly designed to improve student achievement or other outcomes in CS and expand access to and participation in rigorous computer science coursework for traditionally underrepresented students, namely racial minorities and low-income individuals.

B. Project Design and Management Plan

B.1 Goals, Objective, and Outcomes We believe Project {FUTURE} will contribute significantly to the nascent field of elementary computer science education by prioritizing innovations in curriculum integration and impacts on student outcomes, made possible through CS teacher capacity-building and extended professional learning and supported by new instruments critical for the appropriate evaluation of computer science-related interventions. As such, the goal areas of Project: {FUTURE} are to:

1. Expand Access to Computer Science Education for K-5 Students Recognizing the need to build instructional capacity for CS at the elementary level, we begin by implementing and investigating the effects of professional learning for elementary teachers in CS first via pre-established teacher workshops developed by Code.org and later via coaching of grade-specific PLCs. In the culmination of the project, PLC-created exemplar units will demonstrate the potential of CS to enhance positive student learning outcomes on locally-defined high-value measures, a key criterion for CS viability, especially in accountability-oriented school contexts.

2. Contribute Innovations in Professional Learning and Curriculum Integration to Elementary Computer Science Education Building on the achievements in professional learning of Code.org, we will implement a novel teacher "Innovation Incubator" cohort unit development process for elementary CS. In addition to maintaining the curriculum values (I.2), pedagogical approach (I.3), professional values (I.4), and approach to values (I.5) of Code.org, we will also apply the structure Code.org employs for their secondary professional learning programs- a five day intensive summer institute plus four follow-on sessions during the academic year. As an improvement on the one-day workshop, this model brings the programming more in-line with best practices in professional development (Darling-Hammond, Hyler, & Gardner, 2017). The Innovation Incubator will explore connections of computer science with other content areas and extend Code.org's pedagogy of unplugged and plugged activities. Unit exemplars and the process thereto will provide innovative models and produce curricular artifacts, including assessments and evaluation criteria that can be disseminated broadly.

Table 2: Project {Future} Goals and Objectives - Summary

Goal 1: Expand access to computer science education for K-5 students
1.1 Increase to 90% the number of partner school elementary teachers who have participated in professional learning on computer science principles and pedagogy
1.2 Utilize qualitative and quantitative research techniques to identify variables in teachers and school contexts which may impact fidelity of implementation
1.3 Implement 10 computer science-embedded curriculum units to positively impact student performance on locally-defined high-value student outcomes
Goal 2: Contribute innovations in professional learning and curriculum integration to elementary computer science education
2.1 Implement and evaluate the "Innovation Incubator", an intensive teacher cohort professional learning and curriculum development process for 100 elementary teachers across two states
2.2 Design and evaluate 10 exemplar units embedding computer science into identified elementary curriculum areas
Goal 3: Contribute validated instruments and curricular tools to the field of computer science education
3.1 Develop, pilot, iterate, and validate a survey instrument to measure Teacher Attitudes and Beliefs about Computer science (T-ABC)
3.2 Develop, pilot, iterate, and validate an observation instrument, Computer Science Teaching Observation Protocol (CSTOP) to measure desired teacher behaviors and practices in elementary computer science education
3.3 Develop, test, and refine an evaluation tool, Educators Evaluating Excellence in Embedded Computer Science (E4CS) to measure the quality of curriculum units integrating computer science

3. Contribute Validated Instruments and Curricular Tools to the Field of Computer Science Education Perhaps the clearest indication of the nascent nature of computer science education as a field of educational research, especially at the elementary level, is the lack of validated instruments and curricular tools to measure and monitor targeted mediators and desired outcomes. These tools are critical for valid cross-talk and comparison of various interventions. Recognizing the mediating and gate-keeping effects of teachers, administrators, and curricula, we propose the construction of three instruments. First an instrument to measure teacher attitudes and beliefs about CS which can be used to analyze the impact of professional learning experiences. Second, an observation protocol for CS to aid both researchers and administrators in identifying desired CS pedagogy. Third, a curriculum evaluation tool measuring the quality of computer science-embedded units to aid developers and researchers. Targeted publication areas are highlighted throughout the project activities and are summarized in Appendix I.6.

B.2 Project Design and Management Plan To achieve these goals, we define four phases of Project: {FUTURE}, outlined in Table 3, *Overview of Project Phases*.

Phase 1 In our *Outreach & Development Thread*, we apply the pre-existing Code.org elementary computer science teacher workshop *Computer Science Fundamentals* (Appendix I.7) to all partner elementary schools, whose districts are described in Table 4. Workshops are led by facilitators who have completed a rigorous training program through Code.org. Project Coordinators provide assistance with logistics and communication and the faculty Lead Liaisons/Site Observers cultivate reciprocal relationships with their respective school partners. The affiliations and responsibilities of Key Personnel are described in Table 5. One barrier we have identified to participation in our project activities is teacher anxiety in response to new technology, which may be a personal characteristic or a result of a multi-generational workforce. We have budgeted to follow a co-facilitation model, as preferred by Code.org, to ensure that there is always a facilitator available to provide one on one technical support, easing anxiety and ensuring real-time engagement with the workshop

Table 3 Overview of Project {FUTURE} Phases

Year	Phase Description
Year 1	**Phase 1** *Computer Science Fundamentals* Workshop for all K-5 teachers at partner elementary schools
Years 1- 2	**Phase 2** *Deep Dive* Workshop for all K-5 teachers at partner elementary schools
Year 3	**Phase 3** Coaching via school-site PLCs to meet partner school needs based on implementation stage and other constraints (e.g. standards unpacking and alignment, curriculum mapping, instructional coaching, assessment development)
Years 3- 5	**Phase 4** Teacher cohort engages in intensive summer professional learning and curriculum development process, creating, piloting, refining, evaluating, and disseminating a computer science-embedded curriculum unit consisting of both "unplugged" and "plugged" components

activities, while allowing the group to advance as planned. In our *Research & Analysis Thread,* we introduce additional data collection efforts to study, “What shifts in beliefs and attitudes do elementary teachers experience with participation in a CSF workshop?”

Table 4 Partner School Districts for Project {FUTURE}

School District	% FARM	% URM	K-12 Student Population (approximate)	# of schools participating	Lead Liaison/ Site Observer
Bridgeport Public Schools	96%	91%	23,000	6	Ronan
Cooperative Educational Resource Center (LEA)	37%	64%	800	1	Maur
Cooperative Educational Resource Center (Regional Educational Services)	0 - 52%	5 - 65%	111,000	5	Maur
Milwaukee Public Schools	83%	82%	76,000	12	Brylow & Radomski
New Haven Public Schools	59%	86%	22,000	6	Erdil

Hypothesizing that both computer science attitudes (or stereotypes) and self-efficacy play a role, we will draw from existing validated instruments, namely the CS Attitude Survey (Dorn & Tew, 2015), the Science Teaching Efficacy Belief Instrument (Riggs & Enochs, 1990) and the BASICS teacher questionnaire (Outlier Research & Evaluation, 2017) to develop the Teaching Attitudes & Beliefs in CS (T-ABC). Since attitudes and beliefs are complex internal processes, qualitative measures like interviews and focus groups with participants will inform development of the quantitative survey instrument.

Phase 2 In our *Outreach & Development Thread* we extend the professional learning achievements of Code.org via their follow-up elementary computer science teacher workshops *Deep Dive* to all partner elementary schools. Catch-up sessions of *Computer Science Fundamentals* and *Deep Dive* will be offered throughout the grant period to accommodate

Table 5 Project {Future} Key Personnel and Responsibilities

Leadership Team		
Dr. Darcy Ronan	**PI, Project Director- CT** *Asst Professor of Teacher Education, Sacred Heart University*	Project Leadership Research & Analysis Team Outreach & Development Team Lead Liaison/Site Observer- BPS
Dr. Dennis Brylow	**Co-PI, Project Director- WI** *Professor of Computer Science, Marquette University*	Project Leadership Research & Analysis Team Outreach & Development Team Lead Liaison/Site Observer- MPS
Esther Bobowick	**Co-PI** *Director of Professional Development Services, Cooperative Educational Services*	Outreach & Development Team
Eric Radomski	**Co-PI** *Director of Career and Technical Education, Milwaukee Public Schools*	Lead Liaison/Site Observer- MPS Outreach & Development Team
Bonnie Maur	**Co-PI** *STEM Coordinator, Sacred Heart University*	Lead Liaison/Site Observer- CES Outreach & Development Team
Dr. D. Cenk Erdil	**Co-PI** *Asst Professor of Computer Science, Sacred Heart University*	Lead Liaison/Site Observer- NHPS Research & Analysis Team
Support Team		
(New Hire- Job Description Appendix I.8)	**Project Coordinator- CT** *Sacred Heart University*	Project Coordination- CT
Heidi Williams	**Project Coordinator- WI** *K-8 Computer Science Consultant, Marquette University*	Project Coordination- WI
External Evaluation Team		
Theresa Bruckerhoff	**External Evaluator** *Curriculum Research and Evaluation, Inc.*	Research & Analysis Consultant

teachers new to the district or new to a partner school. Meanwhile, in the *Research & Analysis Thread* the scope of the study expands to address, "What teacher and school context variables affect the development of teacher attitudes/beliefs as well as fidelity of implementation?" Hypothesizing that complex interactions of site-specific factors affect implementation trajectories, and that these factors are mediated by inherent and often unspoken hierarchies, we deploy site visits and interviews with teachers and administrators. Interview questions will be adapted from the BASICS questionnaire (Outlier Research & Evaluation, 2017) to identify barriers and supports in the implementation of CS in an elementary school. School-site visits will occur quarterly, with each Lead Liaison working as the primary observer of a subset of schools. As an additional research activity, we will develop and implement an observation protocol (CSTOP) specific to elementary computer science pedagogy in order to observe and analyze computer science instruction. This protocol will draw from existing validated instruments, namely The Framework for Teaching (Danielson, 2013) and the Reformed Teaching Observation Protocol (Sawada, Piburn, Judson, Turley, Falconer, Benford & Bloom, 2002) with content-area guidance from the state-level standards for CS (Connecticut Department of Education, 2017; Wisconsin Department of Public Instruction, 2017).

Phase 3 In our *Outreach & Development Thread* we begin innovating further professional learning supports for elementary computer science by introducing grade-level specific coaching sessions to better understand, "Do enhanced professional learning supports foster the development of computer science attitudes and beliefs, program implementation, and computer science pedagogy" In preparation, our team of Code.org-trained workshop facilitators will receive additional professional learning to transition into the role of coaches. The formation and goals of the PLCs will be collaboratively planned by teachers, coaches, Lead Liaisons, and administrators. Goals areas will be standards unpacking, alignment, curriculum mapping and instructional coaching in computer science pedagogy. As such, the teachers transition from the more passive "workshop participant" role into a more active role as a member of a Community of Practice (Lave & Wenger, 1998) for CS education. In our *Research & Analysis Thread* the teacher survey instrument (T-ABC) and classroom observation instrument (C-STOP) will provide a means to continue monitoring shifts in teacher attitudes and behaviors, respectively.

Phase 4 represents a paradigm shift in the activities of the proposed project, as it begins with a teacher "opt-in" opportunity, whereby CT and WI will each competitively select a representative group of 50 cohort teacher applicants from partner elementary schools. To choose applicants we will employ the Code.org Facilitator application questions, designed and tested to identify those ready to be champions of computer science education in elementary schools. We will take steps to ensure the cohort will be representative of the partner elementary schools, teacher demographic characteristics, grade levels and, if relevant, curricular areas of focus. In this Innovation Incubator, cohort teachers will engage in a two-year unit development and testing process, with each year including a five-day intensive summer session with four follow-on sessions throughout the following academic year to address, "Can the integration of CS into elementary curriculum units enhance CS skills and positively affect other identified student outcomes?". The cohort will launch with a goal-setting session with cohort teachers and their building administrators to identify the locally-defined high-value student outcomes that will be targeted for a unit. For example, an administrator may be planning a school-wide emphasis on reading in the coming school year, or mathematics, or even social/emotional growth. We hypothesize that a computer science-embedded curriculum unit could be developed and implemented to improve student outcomes in any of those areas.

The first summer session (Year 3) will focus on the identification of opportunities to embed computational thinking and computer science concepts into various content areas (planned schedule described in Appendix 1.9). PLCs will form and identify target unit disciplines and grade levels (e.g. fourth grade mathematics), based on teacher interests, assignments, and identified locally-defined high-value outcomes. Each PLC will develop a pilot unit which incorporates CS via unplugged activities to explore the target content, to be implemented and evaluated in the following school year. As such, the PLCs transition from Communities of Practice to Epistemic Communities (Haas, 1992), communities that generate new knowledge in the field of computer science education. The second summer session (Year 4) will refine the units and incorporate the design and development of CS plugged activities. PLCs will collaborate with technical developers to create these plugged activities- web-based open access platforms where students use CS skills to explore the target content. We hypothesize that the collaboration with a computer scientist will be a rich professional learning experience. Implementation of the exemplar unit with the addition of plugged activities will take place in the following academic year. In Year 5 project partners will support PLCs upon evaluating impacts on student outcomes, leading to dissemination of results at both a local and national level.

Program Management and Timeline A detailed overview of the alignment of project activities, outcomes, and milestones is provided in Table 6. A detailed overview of project activities in relation to project years and academic years is included in Appendix I.10.

Plan for Continuous Improvement We have planned for continuous improvement both within and across project phases. One critical means is the solicitation of feedback from participants and other stakeholders at key junctures of the project. Pre-existing mechanisms for feedback are the satisfaction surveys already incorporated into the Computer Science Fundamentals and Deep Dive workshops. Building on this best practice, we will develop a similar survey for Phase 3 which address the extent to which coaching sessions are meeting the professional development needs of teachers. Innovating in this space, the development of new instruments in the early phases of the project (T-ABC and CSTOP) will provide additional metrics to monitor growth in teacher learning and behaviors. Trends in teacher development and activity will be regularly reviewed, including sub-group analysis. Data-informed reflection from each phase can inform the subsequent activity including, but not limited to, trying alternate approaches, clarifying areas of challenge and providing additional supports.

While not the primary focus of the research activity, responses in focus groups and interviews and observations during school visits will likely elicit program feedback. The building administrator interview protocol will include items designed to gather feedback about support and success of implementation. The Leadership Team will monitor staffing to ensure matches between facilitator/coaches and school partners are sustained over time and for addressing improvement areas, up to and including changes in personnel. The Leadership Team will have a joint meeting monthly and a state-specific meeting monthly to monitor project activities, feedback, and outcomes. An Advisory Board comprised of the Leadership Team plus partner school administrators and teachers will meet two times a year to conduct a thorough analysis of grant activities and feedback and identify opportunities to make improvements.

Table 6. Overview of project activities, outcomes, and milestones

Goal 1: Expand access to computer science education for K-5 students							
Outreach & Development Thread				*Research & Analysis Thread*			
Objective/Activity	**Metric**	**Target**	**Timeline**	**Objective/Activity**	**Metric**	**Target**	**Timeline**
1.1 Increase to 85% the number of partner school elementary teachers who have completed professional learning on computer science principles and pedagogy				1.2 Utilize qualitative and quantitative research techniques to identify variables in teachers and school contexts which may impact fidelity of implementation (Publication A)			
1.1.1 Implement Professional Learning Workshop "Computer Science Fundamentals" for K-5 teachers at all partner elementary schools	% participation of K-5 teachers	85%	Y 1	1.2.1 Monitor implementation via usage data of online curriculum platform	# of reports generated	4 per year	Y 1-3
1.1.2 Implement Professional Learning Workshop "Deep Dive" for K-5 teachers at all partner elementary schools	% participation of K-5 teachers	85%	Y 1-2	1.2.2 Measure and monitor teacher attitude and belief data (T-ABC) following successive professional learning workshops (Y1-2) and coaching (Y3)	# of reports generated	2 per year	Y 1-3
1.1.3 Implement coaching via school-site PLCs to meet district needs in implementing computer science (mapping, instructional coaching, aligning)	# of coaching sessions	18 per site	Y 2-3	1.2.3 Conduct interviews with facilitator/coaches, teachers and administrators (Y1-3) and school site observations (Y2-3) and to gain contextual and qualitative insight on implementation trajectories	# visits # inter-views #obser-vations	4/ 4/ 4/ site per year	Y 1-3
1.3 Implement 10 computer science-embedded curriculum units to positively impact student performance on locally-defined high-value student outcomes (Publication Area B)							
1.3.1 Pilot curriculum units with "unplugged" activities	# of units piloted % of PLC teachers piloting	10 80%	Y 4	1.3.2 Evaluate impacts of pilot units on both computer science outcomes and identified non-computer science outcomes	# of reports generated	10	Y 4
1.3.3 Implement curriculum units with both "unplugged" and "plugged" activities	# of units implemented % of PLC teachers implementing	10 80%	Y 5	1.3.4 Use a quasi-experimental model to evaluate impacts of final units on both computer science outcomes and identified non-computer science outcomes	# of reports generated	10	Y 5

Table 6. Overview of project activities, outcomes, and milestones (cont'd)

Goal 2: Contribute innovations in professional learning and curriculum integration to elementary computer science education							
Outreach & Development Thread				*Research & Analysis Thread*			
Objective/Activity	**Metric**	**Target**	**Timeline**	**Objective/Activity**	**Metric**	**Target**	**Timeline**
2.1 Implement and evaluate the "Innovation Incubator", an intensive teacher cohort professional learning and exemplar unit development process for 100 elementary teachers across two states							
2.1.1 Implement, monitor and evaluate Cycle 1 of the Innovation Incubator- a week-long summer intensive with 4 follow-on academic year sessions	% of teachers complet-ing	90%	Y 3-4	2.1.3 Measure and monitor teacher attitude and beliefs (T-ABC) following each Cycle of the Innovation Incubator (Publication C)	# of reports generated	2 per year	Y 3-5
2.1.2 Implement, monitor and evaluate Cycle 2 of the Innovation Incubator- a week-long summer intensive with 4 follow-on academic year sessions	% of teachers complet-ing	90%	Y 4-5	2.1.4 Utilize workshop satisfaction survey and focus groups to gain insight on the teacher experience	# of surveys # of focus groups	100 2 per year	Y 3-5
2.2 Design and evaluate 10 exemplar units embedding computer science into identified elementary curriculum areas							
2.2.1 Identify locally-defined high-priority outcomes in collaboration with local school leaders	% of leaders involved	90%	Y 3	2.2.4 Implement and monitor the use of the **E4CS** to evaluate units in development	# of ratings	2 per unit per year	Y 3-5
2.2.2 Support the development of CS-embedded curriculum units through teacher-designed unplugged activities	# of units	10	Y 3	2.2.5 Implement and support a collaborative action research model to study the impact of teacher developed units (Publication Area B)	# of reports generated	10	Y 5
2.2.3 Support the development of CS-embedded curriculum units, through teacher-and-developer designed plugged activities	# of new plugged activities	10	Y 4-5				

Table 6. Overview of project activities, outcomes, and milestones (cont'd)

Goal 3: Contribute validated instruments and curricular tools to the field of computer science education			
Research & Analysis Thread			
Objective/Activity	**Metric**	**Target**	**Timeline**
3.1 Develop, pilot, iterate, and validate a survey instrument to measure Teacher Attitudes and Beliefs about Computer science (T-ABC) (Publication D)			
3.1.1 Develop, pilot and iterate survey items for the T-ABC adapted from existing validated instruments with teacher workshop participants, using interviews and focus groups to gather feedback and probe relevant attitudes and beliefs	# of iterations # of focus groups # of interviews	3 3 6	Y 1
3.1.2 Administer the T-ABC to teacher workshop participants and conduct a validation study	# of participants	780	Y 1
3.2 Develop, pilot, iterate, and validate an observation instrument, Computer Science Teaching Observation Protocol (CSTOP) to measure desired teacher behaviors and practices in elementary computer science education (Publication E)			
3.2.1 Develop, pilot and iterate structures and categories for the CSTOP adapted from existing validated instruments, using observer and participant debriefs to gather feedback and probe relevant teaching behaviors	# of iterations # of observations # of debriefs	3 18 18	Y 2
3.2.2 Implement the CSTOP during school observations and conduct a study to determine the validity of the instrument	% of sites participating in observations	100	Y 2
3.3 Develop, test, and refine an evaluation tool, Educators Evaluating Excellence in Embedded Computer Science (E4CS) to measure the quality of curriculum units integrating computer science (Publication F)			
3.3.1 Develop structures and language for the E4CS adapted from existing validated tools	# of iterations	2	Y 3
3.3.2 Test the E4CS within the cohort unit development process and gather feedback about the tool from both the givers and receivers of feedback	# of ratings per unit	3	Y 3-4
3.3.3 Refine the E4CS and utilize for review of final unit exemplars	# of ratings per unit	3	Y 4-5

C. Project Evaluation

Curriculum Research and Evaluation, Inc. (CRE) will conduct an independent evaluation of Project {FUTURE}'s implementation and impacts. It will provide formative feedback for project improvement and evidence of fidelity of implementation, and summative information on the impact of the professional learning and embedded curriculum on teacher and student outcomes. Over the project's five years external evaluation will serve as a critical project partner, ensuring that data is effectively used for continuous improvement and informed decision-making on the project design, implementation, and expected outcomes.

Working collaboratively with the Research and Analysis Team during the four project phases, CRE will provide feedback for ongoing program development by examining factors related to successful implementation and providing analysis of implementation and outcome data that meets the What Works Clearinghouse's (WWC) standards with reservations. During the initial project phases the evaluation team will support ongoing improvement of Project {FUTURE} by addressing challenges and informing program corrections and will work with the project team to develop, refine and finalize outcome measures to be incorporated into the summative evaluation. The evaluation will use a mixed methods multistep approach to conduct implementation and impact evaluations guided by the project's research questions:

- What shifts in beliefs and attitudes do elementary teachers experience with participation in a CS workshop?
- What teacher and school context variables affect the development of teacher attitudes and beliefs as well as fidelity of implementation?
- Do enhanced professional learning supports foster the development of computer science attitudes and beliefs, program implementation, and computer science pedagogy?

- Can the integration of CS into elementary curriculum units enhance CS skills and positively affect other identified student outcomes?

Exploration of the relationship between implementation and impacts identified in the project Logic Model will provide the context for interpreting impact findings, for making mid-course adjustments, and for identifying effective strategies that will allow for replication or testing in other schools and settings. Evaluation activities will include critical reviews of the professional learning and supports designed to prepared elementary teachers for embedded CS instruction, the development and implementation of exemplar integrated CS and academic content units, and the development and validation of a suite of evaluation tools for measuring teacher outcomes, curriculum development, and instructional practice. Summative evaluation will examine factors of implementation and impacts on teachers and students to determine Project {FUTURE}'s success in engaging elementary teachers in progressive and sustained professional development in CS education to positively impact student outcomes in CS and other identified areas.

C.1 Quasi-experimental Evidence of Effectiveness The evaluation of Project {FUTURE} will include a focus on Implementation of teacher CS training and curriculum development supports and Impact on teacher attitude, beliefs and instructional development and practice and student learning. Quasi-experimental designs will be used to collect and analyze outcome data on teacher attitude and belief and student learning, supported by qualitative and quantitative implementation and impact data, that will produce evidence of program effectiveness that meets the What Works Clearinghouse's (WWC) Standards with reservations. To measure impacts of the project's extended professional learning experiences (Phases 3 and 4) on elementary teacher's attitudes and beliefs towards computer science, the Research and Analysis Team in collaboration with the evaluator will collect quantitative data through repeat, time-phased administrations of the project validated (Phase 1) T-ABC instrument with participant teachers engaged in extended supports for collaborative curriculum development and implementation (after Phases 2, 3,4). Comparative data collected will be collected through repeat, time-phased administrations of the survey with non-partner teachers outside of the scope of this project who receive training in Computer Science Fundamentals and Deep Dive workshops at Sacred Heart University and Marquette University. A regression analysis will be used to compare scores to measure the impact of Project {FUTURE}'s Phases 3 and 4 on teacher attitudes and beliefs.

Quasi-experimental design will also be used to measure the impact of Project {FUTURE} and the exemplar units on student academic learning. To structure the study, 100 of the 750 trained and supported elementary teachers who worked collaboratively to develop 10 CS embedded curriculum units will integrate the curriculum into their classroom instruction in 30 schools across two states, directly impacting 2,500 students. These phase 4 cohort teachers, while engaged in curriculum development, will identify student learning assessment strategies that have as much rigor as possible given the grade level, with impact areas based on locally defined high-priority outcomes, likely those included in academic areas assessed by the standardized state assessments - the Smarter Balanced Assessment Consortium in Connecticut and the Forward Exam in Wisconsin. Additional data further explaining outcomes will include computer science skill assessment through the Code.org platform embedded assessment puzzles (Code.org, 2018) and unit-based assessments.

The 2,500 students who are enrolled in the classrooms of the trained elementary teachers during Phase 4 will make up the treatment group. For each treatment group a same grade-level non-participant teacher and their students within or across partnering schools will be selected to serve as matched control groups. The Research and Analysis Team in conjunction with the evaluator will work with the school administrators to determine the suitable baseline measures, likely previous year Standardized testing data, and other variables to be consider when assessing equivalency. With expected heterogenous placement of students in classrooms across grade levels at each school site, the evaluation will use a hierarchical linear model (HLM) to conduct propensity score matching for equivalency testing, including consideration of student demographic data (URM status, FARM), attendance rates and other relevant academic variables. Control classroom selection will be modified as needed in order to meet the WWC standard with reservations that treatment and control groups are equivalent within +/- .25 standard deviations, on baseline measures (i.e. Meets WWC Group Design Standards with Reservations, U.S. Department of Education, 2014). With the large number of students included in the study, the sample size will be sufficiently large to detect significant effects.

Previous to the study period, treatment group teachers will have participated in Phases 1-3 of the project and developed and tested for implementation an embedded CS unit of study. This unit plans will be implemented in the treatment classrooms with the purposes of impacting student learning in the areas of computer science and academic learning as measured by pre/post administrations of the Code.org embedded assessments, classroom content assessments, and at a standardized level with content specific areas of SBAC or the Forward Exam.

Students in the control group will engage in content learning through “business as usual’ instruction with impacts measured through content scores on the standardized assessments. Control group teachers may also consider administering the pre/post classroom level content assessment as an additional explanation of impact. A difference in differences analysis will be used to determine impacts on student learning in specific content as measured by the standardized measures.

To accommodate expected attrition among students in the treatment and control group, students who arrive after the groups have been established and the intervention has begun will be collected but not included in the study. In the event that student loss results of non- equivalent groups, the data collected from newly arrived students will be then be included and a logistical regression analysis will be employed to ensure continued equivalency.

C.2 Effective Strategies Suitable for Replication and Testing To supplement the quasi-experimental evidence on the project effectiveness on teacher attitude and belief and improved student learning, and to provide additional information on how Project {FUTURE} can be scaled-up for implementation in additional school districts, the research and evaluation teams will implement additional protocols to measure and document implementation factors. Data will also be collected that explores the quality of the professional learning provided, the impact of the PLC process, including curriculum development and implementation, changes to the school curricular offerings, and challenges and facilitators in implementation. To measure and document these additional implementation strategies and factors, CRE will work with the research team to validate project-developed instruments and to analyze additional sources of implementation data, including observation data, focus group and interview data, program documentation and teacher implementation logs, workshop impact data, and student demographic and attendance data.

Documentation of the innovations in professional learning in CS education and strategies for curriculum integration of CS into the elementary classroom developed by Project {FUTURE} can be used to replicate the project for testing in other settings and in larger scales. Additionally, the project's development and validation of a suite of evaluation tools, including the of the T-ABC to identify which aspects of teacher attitudes towards CS require the most attention at baseline; the CSTOP to observe instructional practice; and the E4CS to measure quality of the curriculum units can be used with other professional learning programs or different teacher populations to measure change in attitude and behavior and instructional practice.

Analysis of the pre- and post-assessment data and supportive quantitative and qualitative implementation and impact data will allow the research team, in collaboration with the evaluator, to develop a model for replicating the professional development process designed to integrate CS instruction into the elementary classroom to improve student learning. Additionally, moderators and mediators, including effects of the program by school context and teacher participant, will be addressed through follow-up data collection efforts to determine the conditions that best support future implementations of the program, information that can be shared with other interested teachers and school districts. The development, implementation, and outcomes of teacher-created CS embedded curriculum unit exemplars by the project's teacher cohort will also serve as an indicator of content areas which provide suitable connections for CS and ideas for CS activities that yield positive changes in student outcomes. Evaluation findings are also expected to support continued replication and testing of the PLC and epistemic community model for innovation and curriculum units themselves and as models of CS curriculum integration with teachers and school districts beyond the study sites.

C.3 Valid and Reliable Performance Data on Relevant Outcomes The program Logic Model and Overview Chart outline the key components of the program, the outcomes of each initiative, and the expected thresholds for successful implementation and effectiveness. Because the expected impact and achievement measures, the project-validated T-ABC, and SBAC and the Forward Exam are standardized tests, the WWC assumes the outcomes meet all the WWC outcome standards. Student demographic, attendance, and academic data will be collected from administrators at each program site. Project developed measures will be validated prior to final data collection efforts to ensure validity of outcome data. Workshop Surveys, Code.org embedded assessments, and classroom assessment data will support data collected from standardized measures, further explaining the outcome data. Qualitative protocols of interview and observation, including feedback surveys and other collected data will be transcribed and entered into a qualitative software package (i.e. Dedoose) for management and analysis.

The research team, working with the evaluator will code data using methods of thematic content analysis (Ulin et al., 2005) to identify and compare themes across program sites and classrooms. Data from multiple sources, both quantitative and qualitative, will be triangulated to identify and inform effective program factors, barriers to success, moderators and mediators. Results will be reported formally and informally to the project team to inform change and annually in formal federal evaluation and performance reports.

C.4 Articulation of Key Project, Components, Mediators and Outcomes The project design, Overview Chart and aligned Logic Model articulate the program's phases and key components, mediators, outcomes, and milestones from both outreach and development and research and analysis threads. Identified thresholds will be reviewed in the program's first year to insure alignment with fidelity measures on professional learning, curriculum development and implementation and student impact, and to accommodate identified mediators and moderators. A triangulation of quantitative and qualitative data will ensure fidelity of implementation and successful realization of the project goals and objectives.

References

Abell, S. K. & Roth, M. (1992). Constraints to teaching elementary science: A case study of a science enthusiast student teacher. Science Education, 76(6), 581-595.

Author. (2018). “The Clinical Practice Imperative: A Pivot Toward Clinical Practice, Its Lexicon, and the Renewal of Educator Preparation” commissioned by the American Association for Colleges of Teacher Education, 2018 released at National Press Club.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84, 191–215.

Batelle for Kids. (2019). Framework for 21st Century Learning. Retrieved from: http://static.battelleforkids.org/documents/p21/P21_Framework_Brief.pdf.

Berg, A. (2012). De-marginalizing science in the early elementary classroom: Fostering reform-based teacher change through professional development, accountability, and addressing teachers’ dilemmas (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3507600).

Bort, H. & Brylow, (D). (2013). CS4Impact: Measuring Computational Thinking Concepts Present in CS4HS Participant Lesson Plans. In SIGCSE 2013: The 43rd ACM Technical Symposium on Computer Science Education, pages 427-432, Denver, Colorado, March 2013.

Carlone, H.B. & Webb, S. M. (2006). On (not) overcoming our history of hierarchy: Complexities of university/school collaboration. Science Education, 90(3), 544-568.

Center on Educational Policy. (2008). Instructional time in elementary schools: A closer look at changes for specific subjects. Washington, DC: Center on Educational Policy.

Century, J., Ferris, K., & Zuo, H. (2019). Finding Time for Computer Science in the Elementary Day. Outlier Research & Evaluation. UChicago STEM Education at the University of Chicago. Retrieved from: http://outlier.uchicago.edu/TimeforCS/findings/.

Chang, K. (2009, November 12). White House Begins Campaign to Promote Science and Math Education. New York Times. Retrieved from https://www.nytimes.com/2009/11/24/science/24educ.html.

Cochran-Smith, M., & Lytle, S. L. (1993). Inside and outside: Teacher research and knowledge. New York: Teachers College Press.

Code.org. (2018). 2018 Annual Report. Retrieved from: https://code.org/about/2018

Code.org(a). (2019). Computer Science Principles. Retrieved from https://code.org/educate/csp.

Code.org(b). (2019). Support K-12 Computer Science Education in Connecticut. Retrieved from https://code.org/advocacy/state-facts/CT.pdf

Code.org(c). (2019). Support K-12 Computer Science Education in Wisconsin. Retrieved from https://code.org/advocacy/state-facts/WI.pdf

Code.org(d). (2019). Professional learning opportunities. Retrieved from: https://code.org/educate/curriculum/elementary-school

Computer Science Teachers Association. (2015). National Secondary Computer Science Survey. ACM and csteachers.org.

Connecticut Department of Education. (2017). Computer Science Standards Progressions. Retrieved from: https://portal.ct.gov/-/media/SDE/Computer-Science/CS_Standards_Progressions.pdf.

Crocco, M. S., & Costigan, A. T. (2007). The narrowing of curriculum and pedagogy in the age of accountability: Urban educators speak out. Urban Education, 42(6), 512-535. doi:10.1177/0042085907304964

CS Fundamentals. (2018). Code.org 2018-2019 Curriculum Guide for Computer Science Fundamentals. Retrieved from https://curriculum.code.org/csf-18/.

Danielson, C. (2013). The Framework for Teaching Evaluation Instrument. 2013 Edition. Retrieved from: http://www.loccsd.ca/~div15/wp-content/uploads/2015/09/2013-framework-for-teaching-evaluation-instrument.pdf.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective Teacher Professional Development (research brief). Palo Alto, CA: Learning Policy Institute.

Dorn, B. & Tew, A.E., (2015) Empirical validation and application of the computing attitudes survey, Computer Science Education, 25:1, 1-36, DOI: 10.1080/08993408.2015.1014142

Dweck, C. S. (2006). Mindset: The new psychology of success. New York, NY, US: Random House. ISBN 9780345472328.

Dwyer, D. (2012, March 19). Skilled workers needed to run high-tech CNC machines. Marketplace, National Public Radio. Retrieved from https://www.marketplace.org/2012/03/19/tech/skilled-workers-needed-run-high-tech-cnc-machines.

Greenwood, A., & Scribner-MacLean, M. (1997). Examining elementary teachers' explanations of their science content knowledge. Annual meeting of the National Association for Research in Science Teaching (pp. 2-18).

Haas, P. M. (1992). "Introduction: epistemic communities and international policy coordination". International Organization, Special Issue: Knowledge, Power, and International Policy Coordination. Cambridge Journals. 46 (1): 1–35.

Jones, C. (2017, March 12). Girls draw even with boys in high school STEM classes, but still lag in college and careers. EdSource. Retrieved from https://edsource.org/2017/girls-now-outnumber-boys-in-high-school-stem-but-still-lag-in-college-and-career/578444.

Lave, J., & Wenger, E. (1998). Communities of practice: Learning, meaning, and identity.

Malyn-Smith, J., Coulter, B., Denner, J., Lee, I., Stiles, J. & Werner, L. (2010). Computational Thinking in K-12: Defining the Space. In D. Gibson & B. Dodge (Eds.), Proceedings of SITE 2010--Society for Information Technology & Teacher Education International Conference (pp. 3479-3484). San Diego, CA, USA: Association for the Advancement of Computing in Education (AACE). Retrieved March 29, 2019 from https://www.learntechlib.org/primary/p/33912/.

Margolis, J. (2017). Stuck in the Shallow End, Updated Edition. Education, Race, and Computing. MIT Press. ISBN 9780262533461.

National Research Council. (2010). Standards for K-12 Engineering Education?. Washington, DC: The National Academies Press. https://doi.org/10.17226/12990.

Outlier Research & Evaluation. (2017). BASICS Study ECS Teacher Implementation and Contextual Factor Questionnaire Measures [Measurement scales]. Chicago, IL; Outlier Research & Evaluation at UChicago STEM Education | University of Chicago.

Payton, F. C. (2003). Rethinking the digital divide. Communications of the ACM. 46(6), 89-91.

Ramey-Gassert, L., Shroyer, M. G. & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. Science Education, 80(3), 283-315.

Riggs, I. & Enochs, L.G. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. Science Education, 74(6), 625-637.

Ronan, D. (2014). Science Specialists in Urban Elementary Schools: An Ethnography Examining Science Teaching Identity, Motivation and Hierarchy in a High-Stakes Testing Climate (Doctoral dissertation). Columbia University Academic Commons. https://doi.org/10.7916/D86T0JS3.

Sanders, J. (2006). Gender and technology in education: A research review. Handbook of Gender in Education, Chris Skelton, Becky Francis, and Lisa Smulyan, editors, Sage Publications, London.

Sawada, D., Piburn, M.D., Judson, E., Turley, J., Falconer, K., Benford, R., & Bloom, I. (2002). Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol. School Science and Mathematics, 102(6), 245-253.

Tilgner, P. J. (1990). Avoiding science in the elementary school. Science Education, 74(4), 421-431.

Ulin PR, Robinson ET, Tolley EE. (2005). Qualitative Methods in Public Health. San Francisco: Jossey-Bass. [Google Scholar]

U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, What Works Clearinghouse.

Wilson, C., Sudol, L. A., Stephenson, C., & Stehlik, M. (2010). Running on Empty: The Failure to Teach K-12 Computer Science in the Digital Age. ACM. Retrieved from https://runningonempty.acm.org.

Wisconsin Department of Public Instruction. (2017). Wisconsin Standards for Computer Science. Retrieved from: https://dpi.wi.gov/computer-science.