Advancing Rural Computer Science (ARCS)

Table of Contents

PROJECT NARRATIVE 2

Section A. Significance 3

A.1. The potential contribution of the proposed project to increased knowledge or understanding of educational problems, issues, or effective strategies 3

A.2. The extent to which the proposed project involves the development or demonstration of promising new strategies that build on, or are alternatives to, existing strategies 6

Figure 1. ARCS Blended Learning Model 7

Section B. Quality of the Project Design 10

B.1. The extent to which the goals, objectives, and outcomes to be achieved by the proposed project are clearly specified and measurable 10

B.2. The extent to which there is a conceptual framework underlying the proposed research or demonstration activities and the quality of that framework 15

B.3. The adequacy of procedures for ensuring feedback and continuous improvement in the operation of the proposed project 16

Section C. Adequacy of the Resources and Quality of the Management Plan 17

C.1. The adequacy of the management plan to achieve the objectives of the proposed project on time and within budget, including clearly defined responsibilities, timelines, and milestones for accomplishing project tasks 17

C.2. The qualifications, including relevant training and experience, of key project personnel 17

C.3. The potential for continued support of the project after Federal funding ends, including, as appropriate, the demonstrated commitment of appropriate entities to such support 19

Section D. Quality of the Project Evaluation 20

D.1. The extent to which the methods of the evaluation will, if well implemented, produce evidence about the project's effectiveness that would meet the WWC standards with or without reservations as described in the WWC Handbook 20

Table 1. Stepped Wedge RCT Design 22

D.2. The extent to which the evaluation will provide guidance about effective strategies suitable for replication or testing in other settings 22

D.3. The extent to which the methods of evaluation will provide valid and reliable performance data on Relevant Outcomes 22

D.4. The extent to which the evaluation plan clearly articulates the key project components, mediators, and outcomes, as well as a measurable threshold for acceptable implementation 25

Advancing Rural Computer Science (ARCS)

PROJECT NARRATIVE

This early stage proposal **Advancing Rural Computer Science (ARCS)** responds to Absolute Priority 1 [AP1]: Demonstrates a Rationale, and Absolute Priority 3 [AP3]: Field Initiated Innovations -- Promotes Science, Technology, Engineering, or Math (STEM) Education, with a Particular Focus on Computer Science. Within AP3, the project addresses the Competitive Preference Priority: Projects designed to improve student achievement or other educational outcomes in computer science. The project will expand access to and participation in computer science coursework for high needs, traditionally underrepresented students in STEM, by which we mean students in communities served by rural local educational agencies, ethnic minority students, and economically disadvantaged students[1]. Project partners include CodeVA, the Virginia Department of Education, and Old Dominion University. The project will be subject to an external evaluation study by faculty at the University of Virginia. The program will address three interconnected areas of need: the shortage of educators equipped to integrate computer science and computational thinking into the elementary curriculum, even though this period is critical for students' preparedness for and persistence in STEM and computer science; the need for students prepared for a workforce in which STEM and computer science knowledge and skills are required; and the challenges associated with educational innovation in rural communities where local educational agencies serve high proportions of disadvantaged students.

ARCS draws on research-based strategies from multiple studies but specifically Meyers, Molefe, Dhillon and Zhu (2015), Taylor, Roth, Wilson, Stuhlsatz, & Tipton (2017), and Maeng, Bell, Konold, and Whitworth (2015), which meet What Works Clearinghouse (WWC) standards without (Meyers et al. 2015, Taylor et al., 2017) and with reservations (Maeng et al., 2015). Both Meyers et al. (2015) and Maeng et al. (2015) demonstrated positive effects for elementary teachers' understanding, confidence and practices as a result of involvement in professional development (PD) including summer institutes and

[1] Economically disadvantaged students are defined as those eligible for free or reduced-priced lunch.

school year professional learning opportunities. Taylor et al. (2017) utilized a PD model incorporating elementary teacher content knowledge deepening and analysis-of-practice, and reported that students of teachers who participated in this model made significantly greater gains in content knowledge (effect size of 0.52 standard deviations) than students of teachers who completed PD focused solely on content knowledge deepening. In addition to these studies, ARCS draws from recommendations of the Regional Educational Laboratory (n.d.) resources on teacher micro-credentialing, the Code.org (2018) *2018 State of Computer Science Education* report, and the report by the National Science and Technology Council's Committee on STEM Education (2018), *Charting a Course for Success: America's Strategy for STEM Education*, which acknowledges specific challenges for STEM education in rural communities.

The ARCS project will address **four goals**: (1) produce of a cadre of qualified educators with computer science microcredentials who will build school-level capacity in computer science instruction (2) develop accessible, field-tested instructional materials that (a) integrate computer science curriculum standards into core elementary subject areas, and (b) use student performance assessments as a tool for evaluating the impact of doing so; (3) increase affective and cognitive readiness for pursuing rigorous STEM and computer science coursework among students from high needs and underrepresented groups; and (4) establish high-quality evidence that will support ARCS program sustainability and expansion.

Section A. Significance (25 points).

A.1. The potential contribution of the proposed project to increased knowledge or understanding of educational problems, issues, or effective strategies.

Problem statement. In 2018, the United States had an estimated 2.4 million unfilled STEM and computer science positions within its workforce. Unchecked, this number will continue to rise and it is estimated that by 2020, more than 50% of jobs in the U.S. will require some degree of STEM literacy (Carnevale, Smith, & Strohl, 2013; Smithsonian, n.d.). Although there is widespread, cross-sector agreement about the need to increase the percentage of students who are literate in and prepared for STEM and computer science careers (National Science and Technology Council Committee on STEM

Education, 2018; Google & Gallup, 2017), particular geographical and demographic groups of students and educators face significant barriers. For example, educators in rural and economically disadvantaged school districts often lack access to high quality professional development, which is a common means by which teachers gain subject matter expertise as well as pedagogical knowledge (Abell, 2007). Since teachers' content knowledge and pedagogical self-efficacy are associated with student achievement (Supovitch & Turner, 2000), initiatives aimed at improving student outcomes must provide evidence-based teacher professional development.

Similarly, programs must include specific strategies for overcoming systemic factors that impede access to computer science. Currently, schools with high populations of underrepresented minority (URM) students and/or economically disadvantaged students are unlikely to provide computer science coursework. The issue is also particularly acute in rural areas, as only 29% of America's rural schools provide instruction in computer science (Code.org, 2018). Improved computer science access for URM students is critical if our nation is to meet its *Strategy for STEM* aspirational goal of increasing diversity, equity, and inclusion in STEM subject areas (National Science and Technology Council Committee on STEM Education, 2018). To address the workforce need as well as systemic disparities, states have begun to enact specific policies expanding access to computer science education. Policies include creating a state plan for K-12 computer science education, establishing state curriculum standards for computer science, and implementing certification pathways through which teachers can become recognized as experts (Code.org, 2018). Virginia is at the forefront of the adoption of computer science standards, having worked toward the development of the *K-12 Computer Science Standards of Learning* over the past few years and mandating the integration of these standards by Fall of 2019. However, very few school districts in Virginia currently teach computer science at the elementary level. The scale of need is overwhelming, but our mission is to develop a practical, sustainable model for delivering high-quality PD along with the necessary supports to ensure that students receive computer science education before entering middle and high school.

High quality professional development should be supplemented by classroom level strategies that develop attitudes and skills predictive of students' STEM and computer science persistence (Faber, Unfried, Wiebe, Corn, Walker Townsend & Collins, 2013). In particular, students' interest and self-efficacy must be cultivated alongside their knowledge and skills. Prior studies point to the importance of beginning this process at the elementary school level (e.g. Siegler et al., 2012; The Women's Foundation of Colorado, n.d.), because indicators of STEM and computer science persistence begin to fall at an early age among underrepresented groups, including Black students (Dickerson, Eckhoff, & Stewart, 2014; Ireland, D., Freeman, K.E., & Winston-Proctor, C.E, 2018), rural students (Chittum, Jones, Akalin, & Schram, 2017), and females (Connors-Kellgren, Parker, Blustein, & Barnett, 2016). One effective approach is to combine culturally responsive pedagogies (Brown-Jeffy & Cooper, 2011) that include ideas that speak to the lived experiences and future aspirations of rural and minority students (Goodpaster, Adeokun & Weaver, 2012; Margolis, Estrella, Goode, Jellison Holme & Nao, 2008; National Academy of Engineering, 2008) and integrate new content into existing subject areas (Sáez-Lopez, Román-González & Vázquez-Cano, 2016), since this both improves the likelihood that teachers will adopt and implement instructional change, and provides channels for culturally responsive pedagogies and local curricular applications that reach students through core elementary subject areas such as reading, writing, mathematics, science, and social studies (Margolis, et al., 2008).

Project contribution. ARCS is designed to improve students' computer science exposure in elementary classrooms by increasing teacher computer science content and pedagogical knowledge and self-efficacy, and improving instructional skills to teach computer science through an interdisciplinary lens. The major activities of the project consist of three components: face-to-face summer institutes, web-based PD and support provided through a Networked Improvement Community (NIC; McKay, 2017), and classroom implementation. The project will provide sustained and on-going learning experiences, and a coaching model will be employed in year two to support classroom implementation and sustainability. Teacher cohorts will move through ongoing PD over a two-year period and will build a NIC that provides opportunities for sharing of resources, experiences, and knowledge. Participating teachers will demonstrate the acquisition of knowledge and integration strategies through an innovative microcredentialing process where their understanding and application of integrative computer science strategies will be assessed in alignment with new legislation that establishes this mechanism for recognizing teacher mastery in this area (Virginia Legislative Information System, 2019).

The ARCS project will increase understanding of how teachers develop the capacity to implement instructional changes in elementary classrooms such that large percentages of URM students are prepared to engage in STEM and computer science coursework. Specifically, the project will provide scholarly and practical answers to questions about ways in which successful communities of practice can emerge among teachers who are working in a variety of challenging environments, including rural schools and schools with high URM populations not previously exposed to computer science concepts. As such, its findings will be of significance for other initiatives seeking to impact the approximately 30% of American students who attend rural schools (Young, 2003). It will explore and articulate threads connecting state level policies with district and building level participation and subsequent adoption of evidence-based practices. Most importantly, the project will contribute to process- and outcome-level understanding of the challenges and successes experienced by students as they consider ways in which computer science topics such as programming, computational thinking (Wing, 2008), and computing systems connect with everyday content areas. It will extend existing models that connect perceived teacher support to URM student interest and perceived competency in computer science, in rural settings that are generally underrepresented in the literature (Hardre, 2008). It will also help to answer questions that remain following early exploration in micro-credentialing by districts and states (Will, 2017).

A.2. The extent to which the proposed project involves the development or demonstration of promising new strategies that build on, or are alternatives to, existing strategies.

To support ARCS' proposed goals, project collaborators will implement a blended professional learning model to improve participants' content and pedagogical knowledge and instructional practice (see Figure 1). PD will be provided through two formats, face-to-face and online, to sustain teacher interest and motivation and continue knowledge development. This approach will address some of the noted shortcomings of online interaction as well as capitalizing on its strengths (Blitz, 2013). For example, the online environment removes the barrier of distance, which is a noted challenge for rural districts seeking to use learning communities (Ryoo, Goode & Margolis, 2016). It also permits mentoring between experienced and novice teachers, and permits equitable access to digitally stored resources. To best support successful integration of the new computer science content, the PD will be designed to build new knowledge on existing knowledge, making connections from previous experiences to the current context (NRC, 2007). While evidence supports this as a successful approach to student learning, these principles also apply to teachers as adult learners and will be incorporated into the ARCS PD model.

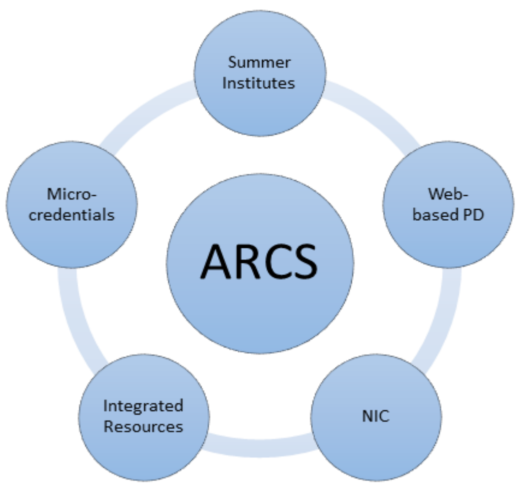

Figure 1. ARCS Blended Learning Model

Professional development. The ARCS PD model includes two intensive summer institutes and school-year participation in analysis-of-practice within a NIC (McKay, 2017), building on previous research by Meyers et al. (2015), Maeng et al. (2015), and Taylor et al. (2017). Meyers et al. focused on PD that helped teachers form a community of learners through activities including lesson design, collegial supports, and a blended learning environment. They found statistically significant gains for participating teachers' students in the area of mathematics achievement. In a study of science teacher PD, Maeng et al.

(2015) showed that PD could be an effective mechanism for increasing teachers' knowledge and confidence with particular forms of pedagogy. The program associated with this study incorporated active learning, coaching, and collective participation by teachers. Finally, Taylor et al. (2017) engaged elementary teachers in PD that helped them deepen their science content knowledge and learn high-leverage teaching strategies, then supported them to incorporate these strategies into instruction and analyze and reflect on their successes and opportunities for improvement. Students of teachers who completed this PD model showed significantly greater gains in science content knowledge than students whose teachers completed a PD focused solely on increasing their content knowledge. Following the second summer institute, participating teachers will also serve as a coach within their respective schools to support expansion and sustainability of integrative computer science lessons (Code Virginia, n.d.).

Microcredentials. One signature innovation of the project is its leveraging of the growing interest in digital badging among educators and its alignment with newly executed legislation in Virginia that permits "the Department of Education to establish a microcredential program for the purpose of permitting any public elementary or secondary school teacher…to complete additional in-person or blended coursework and earn microcredentials in science, technology, engineering, and mathematics, including computer science, for which there is a high need for additional qualified teachers" (Virginia Legislative Information System, 2019). Microcredentials create packets or stacks of qualifications that allow participants to create a demonstrable, visual representation of their effort and skill around a specific topic such as curricular integration, technology use, instructional design or, in this case, integrating computer science within the elementary curriculum (Crow & Pipkin, 2017; DeMonte, 2017; Lemoine & Richardson, 2015; National Education Association, n.d., Tracey, 2014). They also allow for personalized learning along an individual path, as teachers can work collaboratively with their administration to define areas in which they would like to focus, and use the microcredential process to create a measurable way of monitoring progress towards a goal (Acree, 2016; Carey & Stefaniak, 2018). To earn a microcredential, a teacher must demonstrate evidence of mastery of the topic (Crow & Pipkin, 2017).

This requires an assessment such as an online test or submission of materials that can be reviewed by an expert. One benefit for teachers, who may move among school systems, is that earned credentials are transferable. They are therefore visible to administrators who may otherwise not know that a candidate for employment or promotion has skills that would be advantageous for the school. Teachers participating in ARCS will have the opportunity to earn four microcredentials over the course of the program, one for each of the following content areas: (1) Introduction to Computer Science Principles, Digital Impact, and Digital Citizenship; (2) Computing Systems, Networks and the Internet, and Cybersecurity; (3) Algorithms, Programming, Data and Analysis, and; (4) Lesson Integration, which will be a Performance Microcredential requiring materials submission and review.

Accessible, field-tested instructional resources. Prior to employing integrative computer science curriculum, the conditions and cultures that support this learning must be in place. Teachers will build on experiences gained through participation, from content knowledge to integrative approaches to instruction, to develop and implement lessons that incorporate computer science into reading, writing, math, science and social studies education curricula. Teachers will work individually and collaboratively to implement their integrated lessons and resources in their classrooms, with school-year support through their established NIC. This interdisciplinary approach supports the development of teacher self-efficacy and attitudes toward computer science, while placing student-centered classrooms at the forefront of the learning process (Niess & Gillow-Wiles, 2013). It also ensures that teachers facilitate their own learning as they work within a community of practice to establish lessons and resources that are personalized to their own teaching style, community, and classroom. To promote sustainability and project expansion, we will develop an online repository of these lessons where teachers can view, download, share and comment on lessons and anonymized examples of students' work (Beach, 2012). This will promote pilot testing and revision of resources. Final versions will be stored and maintained by project partners. Prior syntheses of research on the availability of online instructional resources has noted specific, positive outcomes including enhanced efficacy to teach effectively in a content area, enhanced subject matter knowledge, collaborative data analysis and interpretation, and collective knowledge dissemination (Blitz, 2013).

Culturally responsive pedagogy. Improving URM students' sense of social belonging and self-efficacy for STEM subject areas can augment the positive effect of active-learning pedagogies on students' performance in science (Ballen, Wieman, Salehi, Searle & Zamudio, 2017). Scholars have emphasized the use of pedagogies designed to appeal to diverse learners, such as learning computer science principles through discussions of culturally and contextually relevant issues, and focusing on how computer science impacts people, societies, and communities (Goodpaster, Adedokun, & Weaver, 2012; Margolis, Good & Bernier, 2011; National Academy of Engineering Committee on Public Understanding of Engineering Messages, 2008). In addition, some scholars have emphasized the use of a strengths-based narrative when communicating about opportunities within rural communities (Winchester, 2009, 2011). The ARCS project will build on existing principles of culturally responsive pedagogy to embed instructional content and strategies that will inform and appeal to students in rural settings and students who may otherwise lack interest in STEM and computer science. Since prior research in this area has tended to focus on interventions at the secondary and post-secondary levels, the ARCS project will contribute to understanding of the ways in which these approaches can be modified and transferred, or redesigned for the elementary level, to promote affective variables of import such as social belonging and self-efficacy as well as students' computer science knowledge and computational thinking skills.

Section B. Quality of the Project Design (35 points).

B.1. The extent to which the goals, objectives, and outcomes to be achieved by the proposed project are clearly specified and measurable.

Goal 1 of the ARCS project is to produce a cadre of qualified educators who can implement computer science lessons and build school-level capacity in computer science instruction. This goal will be achieved by the **objective** of providing two summers and one school year of intensive PD to two cohorts of elementary teachers (*N*=440) in rural and semi-rural areas of Virginia. PD will equip participants to complete the microcredentials.

Teacher PD. Intensive, multi-day institutes will take place each summer, with teachers participating over two consecutive summers. During the first summer institute, teachers will learn fundamental principles of computer science and will be introduced to the six threads of the Virginia Computer Science Standards of Learning: (1) Algorithms and Programming, (2) Computing Systems, (3) Cybersecurity, (4) Data and Analysis, (5), Impacts of Computing, and (6) Networking and the Internet. Teachers will acquire instructional strategies for integrating these threads into elementary instruction in reading, writing, science, mathematics, and social studies. They will acquire pedagogical knowledge and assessment literacy designed to enable them to teach and assess students' understanding and acquisition of computer science concepts and skills. Teachers will receive technology-enhanced materials that will promote the successful implementation of the strategies and skills developed at the institute. Teachers will work towards the goal of developing additional integrative lessons and will examine adult learning processes, which will prepare them to participate in the upcoming NIC and, eventually, to act as a building level coach. During the second summer institute, teachers will examine the six threads in more detail, acquire additional instructional resources for integration into core elementary subject areas, and continue to examine evidence-based practices for supporting and coaching other teachers (CodeVA, n.d.).

School year PD will take the form of a Networked Improvement Community (NIC; McKay, 2017). NICs are professional learning groups that possess four key characteristics: they focus on a well-specified aim; they are guided by a deep understanding of a problem and develop a theory of change to solve it; they deliberately attend to improvement metrics in order to demonstrate movement towards an intended solution; they are coordinated such that educational interventions can be implemented in varying contexts (LeMahieu, 2015). The NIC will be guided by a CodeVA-trained facilitator and will build on collegial relationships established during the summer institute. This will allow teachers to work collaboratively to undertake analysis-of-practice towards the identified problem of practice—computer science cross-curricular integration. Guided by a rubric that is based on the CodeVA Lesson Planning Implementation Guide and used to evaluate the Lesson Integration Microcredential, teachers will develop, implement, and provide feedback on integrated lessons. To supplement this process, teachers will have access to a suite of webinars that have been created by CodeVA facilitators (e.g. Decoding the Computer Science SOLs, n.d.). Webinars will focus on topics such as integrating computer science standards into elementary subject areas, teaching computer science for exceptional learners, and assessing students' understanding of computer science principles. The NIC component will prepare teachers to develop materials that will support the Lesson Integration microcredential that will focus on the implementation and assessment of students' integrated computer science learning. Teachers' learning will be enhanced by subsequent participation during the summer immediately after the implementation year.

Goal 1 outcomes will be measured by the number of teachers successfully completing the PD program, including the number who receive microcredentials in: (1) Introduction to Computer Science Principles, Digital Impact, and Digital Citizenship; (2) Computing Systems, Networks and the Internet, and Cybersecurity; (3) Algorithms, Programming, Data and Analysis; and (4) Lesson Integration.

Goal 2 of the ARCS project is to provide a suite of accessible, field-tested instructional materials for classroom use. This goal will be achieved through a **resource development objective**.

This objective will be measured through systematic collection and refinement of participant-developed lessons that demonstrate the integration of computer science curriculum standards into core elementary subject areas. Participating teachers will share lessons via the NIC and will submit lessons as partial fulfillment of the Lesson Integration microcredential. Lessons will be reviewed by the project leadership team, including CodeVA experts, VDOE STEM Education staff, and Computer Science and Education faculty at Old Dominion University. The **outcome** will be the submission of lessons to the VDOE, which will work with CodeVA to make the resources available to teachers through an open-access repository.

Goal 3 of the ARCS project is to increase affective and cognitive readiness for pursuing rigorous STEM and computer science coursework among students of participating teachers, with a particular focus on historically underrepresented groups including low-income students, students in rural settings, Black and Hispanic students, and female students. This goal will be achieved through the **objective** of teachers' implementation of lessons that integrate computer science into core elementary subject areas, including reading (e.g. proofing, syntax), writing (e.g. sequencing, planning), mathematics (e.g. categorization, rules), science (e.g. loops, cycles), and social studies (e.g. networks). In addition, this component will increase student readiness for rigorous STEM and computer science coursework in later grade levels. Appendix I presents sample integration topics for mathematics, science, and language arts.

The delivery of lessons will implement principles of culturally responsive pedagogy (Ladson-Billings, 2000; Leonard, Mitchell, Barnes-Johnson, Unertl, Outka-Hill, Robinson, & Hester-Croff, 2018) that leverage students' interests and experiences to facilitate understanding of curricular concepts, and evidence-based instructional strategies that promote productive collaboration and cooperation among students (Gillies, 2014). Key principles include forming interdependent teams, establishing group goals and individual accountability, teaching communication and problem-solving skills, and integrating cooperative learning with other types of instructional strategies (Slavin, 2014).

Goal 3 will be assessed through two separate student outcomes. The presence of negative attitudes or views of themselves in relation to computer science has been identified as a hindrance to participation in the field, particularly for students from underrepresented backgrounds (Washington, Grays, & Dasmohapatra, 2016). Students' **affective readiness** for computer science at the upper elementary level increases the likelihood of participation in stand-alone computer science coursework as it becomes available in middle school and beyond. As such, the ARCS project will target students' affective readiness to pursue rigorous coursework in middle and high school. Affective readiness will be assessed by students' responses to a survey of attitudes towards computer science, and self-efficacy toward computational thinking. Items from validated instruments will be utilized, with adjustment of language/phrasing as needed for elementary students. This assessment will be administered at the beginning and end of the year in grades three through five. This objective will provide teachers, administrators, researchers and districts with accessible protocols for assessing the affective impact of a computer science initiative at the elementary level.

The second **student outcome** focuses on the creation and implementation of student performance assessments as a tool for evaluating the impact on student learning. The VDOE has a current statewide effort to embed performance assessment into all classrooms across Virginia. The catalyst for this work was the removal of five state standardized tests in 2015, the adoption of Virginia's new Standards of Accreditation, and the focus on Deeper Learning (DeeperLearning4All.org, n.d.; Virginia Department of Education, 2014, 2019). Currently, districts across the state in collaboration with VDOE have developed numerous performance assessments where standardized assessments were discontinued. These performance assessments are scored using a detailed rubric that is aligned with the content and objective of the lesson and sufficient to detect growth from pre- to post-lesson. The development of the student performance assessment and its scoring rubric will be led by STEM education and assessment specialists at the VDOE. The assessment will be implemented in grades three, four, and five and will satisfy the current state performance assessment mandate. This goal 3 **outcome** will assess students' knowledge and understanding of integrative computer science as they analyze and solve complex problems utilizing an interdisciplinary approach to teaching and learning.

Goal 4 of the ARCS project is to establish high-quality evidence for project impact and outcomes that can support iterative improvements, sustainability, and expansion. This goal will be achieved through the **objective** of the careful integration of data from formative evaluation efforts with external evaluation through a complete stepped wedge randomized control trial (SW-RCT). For more information about the formative evaluation efforts, see section B.3. For information about the SW-RCT, see section D. Its outcome will include scholarly and practitioner oriented articles, policy briefs, and a mid-phase proposal.

B.2. The extent to which there is a conceptual framework underlying the proposed research or demonstration activities and the quality of that framework.

The project level **logic model** is presented in **Appendix G: Logic Model**. It demonstrates the conceptual framework that guides the execution and interpretation of the proposed research and demonstration activities. In addition, we provide a participant level theory of change to demonstrate the quality of this framework.

Participant Level Theory of Change. Underlying the proposed project is a social justice imperative that all students and teachers should have access to meaningful computer science education (Leonard, Mitchell, Barnes-Johnson, Unertl, Outka-Hill, Robinson & Hester-Croff, 2018). Interventions must be of sufficient quality and robustness to be effective in a wide variety of specific contexts, while also being sympathetic to diverse learner needs and committed to the assumption that educational processes can make a difference at the student level (Brown-Jeffy & Cooper, 2011). Without such attention, instruction may contribute to rather than address educational inequities (Savage, Hindle, Meyer, Hynds, Penetito & Sleeter, 2011).

Teachers' change. Implementation of even rudimentary computer science lessons can promote teachers' interest in and self-efficacy for computer science integration (Rich, Jones, Belikov, Yoshikawa, & Perkins, 2017). However, compared to traditional PD programs, engagement in ARCS will dramatically increase the number of hours of professional learning teachers typically receive in addition to expanding opportunities for classroom implementation of integrative computer science lessons (see **Appendix I:** Participant level theory of change). Additionally, through their NIC, ARCS participants will not only be provided extensive professional learning, they will be provided ongoing support in the form of peer mentoring. The multi-faceted professional learning approach provided through the project will increase opportunities for teachers to engage in high-quality and meaningful experiences that go well beyond the one day "sit and get" workshops. Further, the attainment of microcredentials will promote participants in a manner not yet experienced in Virginia in that the microcredential is an artifact that represents a particular community to which the holder of the credential is affiliated (Davis & Singh, 2015; Lave & Wenger, 1991). This indicates an appreciation for teachers' time and effort towards the integration of computer science standards and their decision to become early adopters of computer science in the Commonwealth.

Students' change. We employ a deliberately broad definition of culturally responsive pedagogy to include attention to students' personal, community-based strengths, values, and achievements (Gay, 2010) as well as inclusive instructional practices that promote collaborative engagement (Slavin, 2014; Virginia Department of Education, n.d.). The student level model of change draws from literature that emphasizes that culturally relevant, evidence-based instructional strategies can improve students' perceived and actual competence (Hardre, Sullivan & Crowson, 2009).

B.3. The adequacy of procedures for ensuring feedback and continuous improvement in the operation of the proposed project.

Formative evaluation and continuous improvement through participant feedback are an integral component for this Early Stage proposal and will be key to the program's success. Project personnel will work collaboratively with the external evaluators to review implementation data that will inform improvement of program resources, resource availability and usage, and PD practices in order to best suit participants' needs. The external evaluation is designed to continually gather data from participants throughout the project period, with seven administrations[2] of surveys designed to capture teachers' computer science content and pedagogical knowledge, self-efficacy for teaching integrative computer science, and/or perceptions of the quality of the PD and resources provided through the ARCS program. Specifically, the team will review data gathered across all time points to assess the implementation fidelity (see Section D below) including data on both effective and ineffective program components, and data that will assist the project team to better facilitate the implementation of the program. The formative

[2] Teacher surveys will be administered before and after the year one summer institute, quarterly during the project school year, and after the year two summer institute.

evaluation component will be led by Dr. Shanan Chappell Moots, Director for Research Analytics in The Center for Educational Partnerships at Old Dominion University. Dr. Chappell Moots has participated in several federal-level evaluations and has extensive experience in educational systems redesign (Wilson & Daviss, 1994). The formative evaluation of ARCS will focus on participant perceptions and experiences, incorporating teacher voice to align program elements to reflect participant needs and to achieve intended outcomes. Formative evaluation project personnel will provide aggregated findings from continuous data review to the PD development and implementation team after each data collection point, highlighting strengths and weaknesses of the program and providing recommendations for program improvement.

Section C. Adequacy of the Resources and Quality of the Management Plan (20 points).

C.1. The adequacy of the management plan to achieve the objectives of the proposed project on time and within budget, including clearly defined responsibilities, timelines, and milestones for accomplishing project tasks.

A team of experienced, qualified education and research professionals will collaborate to achieve the objectives of the ARCS project. The team will be led by Project Director Dr. Joanna Garner, Executive Director of The Center for Educational Partnerships at Old Dominion University. Collaborators include personnel from the Virginia Department of Education, CodeVA and additional faculty from Old Dominion University. An external team from the University of Virginia, led by Dr. Jennifer Maeng, will conduct the evaluation. ARCS will be guided by a management plan that clearly defines responsibilities, timelines and milestones for accomplishing project tasks (see **Appendix I:** Project Milestones).

C.2. The qualifications, including relevant training and experience, of key project personnel.

The ARCS project is led by multiple project partners working collaboratively to support ongoing and sustained professional learning and classroom implementation for elementary computer science integration. The ARCS leadership team (see **Appendix B**: Resumes of Key Personnel) will be led by Dr. Joanna Garner. Dr. Garner has served on three federal-level and six state-level STEM education-related grants that have provided STEM PD for elementary and secondary school teachers in Virginia and post-secondary students across the country. She also has experience conducting evaluations for STEM programs on projects funded by federal agencies including the Office of Naval Research and the National Science Foundation. Joining Dr. Garner is Dr. Tina Manglicmot, Director of Science, Technology, Engineering and Mathematics (STEM) for the Virginia Department of Education (VDOE). Dr. Manglicmot will lead the instructional alignment of all project content to the *Virginia Standards of Learning* and will serve as liaison to the Commonwealth for policy and practice related to microcredentialing and will oversee the development of the student performance assessment.

The PD portions of the project will be led by Rebecca Dovi, Director of Education for CodeVA. Dovi is a master teacher with more than 15 years of experience in the classroom and a decade of experience doing PD at the state and national level. She serves on the Education Advisory Council for Code.org, and contributed to the Virginia Computer Science Standards of Learning. Leading the development of the microcredential platform content will be Mr. Robert Doherty, Director of Prior Learning Assessment at the ODU School of Continuing Education and Dr. Desh Ranjan, Computer Science Professor at ODU.

The ARCS team possesses a proven track record in teacher PD (e.g., Maeng et al., 2015; Garner & Loney, 2012) and a history of effective collaboration with state and local agencies on Mathematics and Science Partnership awards (Garner & Loney, 2012; Garner & Loney, 2014). The proposal is submitted with an understanding of the importance of sustained and meaningful partnership among collaborators and a commitment to continuing our work well beyond the grant cycle. In addition, the project will enhance current research around effective professional learning. It will accelerate statewide efforts in microcredentialing as a means of licensure support. By creating a structure for the use of microcredentialing as a product of teacher training, the project team will be able to inform state policy and expand opportunities to credential in other content areas. The project has already been endorsed by a number of Virginia school districts (see **Appendix C**, Letters of Support).

C.3. The potential for continued support of the project after Federal funding ends, including, as appropriate, the demonstrated commitment of appropriate entities to such support.

Commitment to continued support of the project. Virginia has recently taken steps towards implementing policies associated with the increased adoption and integration of computer science (National Science and Technology Council Committee on STEM Education, 2018). The state Board of Education has approved the Virginia Department of Education Computer Science Standards of Learning, and mandated that they be taught as soon as the 2019-2020 school year. Moreover, new state legislation *Virginia SB 1419 Microcredential Program*, which granted the Virginia Department of Education the mandate to enact micro-credentialing pathways for STEM + CS teachers, adds to the state's readiness to adopt and continue to support this component of the ARCS project. The state also continues to emphasize its focus on digital literacy among teachers and students through new college and career readiness initiatives including the *Profile of the Virginia Graduate* (Virginia Department of Education, n.d.).

CodeVA is a non-profit organization with funding sufficient to sustain the PD program beyond the ARCS project. CodeVA will continue to provide PD at no-cost to teachers across the state. The VDOE is committed to the support of computer science integration through its provision of key personnel and positions, including the Director of STEM, and its Director for Computer Science. The Center for Educational Partnerships at ODU is a unit with sufficient funding to continue to act as a point of liaison between the VDOE, the ODU School of Continuing Education, and school divisions across the state that wish to recognize teachers through a computer science microcredential.

In kind and matching funds. Project partners have committed to providing in-kind funds. CodeVA has committed to $108,210.67 of in-kind funds, or $541,053.35 across the five years of the project. The Virginia Department of Education has committed to $16,750 per year for a total of $83,750 across the life of the project. See **Appendix H** for details.

Section D. Quality of the Project Evaluation (20 points).

The external evaluation of ARCS will be led by Dr. Jennifer Maeng, Research Assistant Professor at UVa's Curry School of Education. Dr. Maeng has managed several large-scale program evaluations that include experimental and quasi-experimental research designs and formative components. Her role leading the evaluation of ARCS will build on a previous experience as the project director for the external evaluation of the *Virginia Initiative for Science Teaching and Achievement* (VISTA) project, a US DOE Investing in Innovation (i3) validation grant. In the present collaboration, UVa will support ARCS through evaluation of *implementation fidelity* and a *randomized controlled trial impact study* designed to meet What Works Clearinghouse (WWC) group design standards without reservations.

D.1. The extent to which the methods of the evaluation will, if well implemented, produce evidence about the project's effectiveness that would meet the WWC standards with or without reservations.

Impact Study. ARCS will equip K-5 teachers with content and pedagogical knowledge, and self-efficacy for teaching CS-integrated lessons; and promote K-5 students' CS knowledge and affect towards CS (see Appendix G: Logic Model). Thus, the impact study will address the following five **confirmatory research questions**: (1) How does ARCS impact CS content knowledge among participating K-5 teachers as compared to non-participating teachers? (2) How does ARCS impact CS pedagogical knowledge among participating K-5 teachers as compared to non-participating teachers? (3) How does ARCS impact CS self-efficacy among participating K-5 teachers as compared to non-participating teachers? (4) How does ARCS impact student affect related to CS among K-5 students of participating teachers as compared to the students of non-participating teachers? and (5) How does ARCS impact student CS knowledge among K-5 students of participating teachers as compared to students of non-participating teachers?

ARCS also seeks to verify proficiency in teachers' CS knowledge and pedagogical skills through microcredentialing and build school level capacity to integrated CS into K-5 instruction. The impact study will therefore also answer the following **exploratory research questions**: (1) How many participating teachers earned microcredentials through ARCS? (2) What are participating teachers' perceptions of the microcredentialing process? (3) How does CS-integrated instruction among K-5 teachers change over the course of participation in ARCS?

The impact of ARCS on these outcomes will be evaluated through a complete stepped wedge randomized controlled trial (SW-RCT; Hemming, Haines, Chilton, Girling, & Lilford, 2015). This pragmatic design allows for teachers initially randomized into the control condition to be exposed to the intervention a year after randomization. This design is particularly appropriate given the 2-year duration of the ARCS program in that teachers initially randomized into the control condition will need not wait the full two years to begin receiving the treatment, but will begin the intervention after their baseline (control) year. In addition, SW-RCTs facilitate recruitment because control teachers know that they will receive the desired treatment after one year, which is of particular importance for this project given the mandated implementation of CS standards in fall 2019 by the VDOE.

Recruitment of Teachers/Sample. K-5 teachers from identified rural divisions will be included in one of two cohorts in the SW-RCT impact study (see **Appendix F**: Eligibility Checklist and List of Rural Codes). Cohort 1 will begin treatment in year 1, with Cohort 2 beginning in year 3. Combined, divisions in Cohort 1 have 61 elementary schools with 2,309 K-5 teachers and 27,877 students. Divisions in Cohort 2 have a combined 34 schools with 1,186 K-5 teachers and 15,415 students.

The evaluation team will randomize teachers at a ratio of 50% to treatment and control condition. Each cohort will be randomized at the individual level. We calculated a minimal detectable effect (MDE) of .22, assuming a conservative *n* of 440 across both cohorts, an alpha level of .05, and power of .80 using Optimal Design Software (Spybrook et al., 2013) for teacher-level analyses (table 1). This estimate assumes school-level covariates (e.g. percent minority, percent economically disadvantaged, school size) that explain 30% of the variance. Student level outcomes are estimated as two-level cluster randomized trials with students nested within teachers. We calculated a student-level MDE assuming an alpha level of .05, power of .80, teacher *n* of 440, student *n* per teacher of 20, intraclass correlation coefficient of .10, and a school-level covariate explaining 30% of the variance for an MDE of .09. Estimates were also calculated reducing the teacher and student *n* to account for attrition[3], revealing an MDE of .11.

Table 1. Stepped Wedge RCT Design (total of 440 teachers)

Cohort	Treatment Onset	Year 1 2020-2021	Year 2 2021-2022	Year 3 2022-2023	Year 4 2023-2024	Year 5 2024-2025
1	Immediate	TY1: 110 teachers	TY2: 110 teachers	--	--	
	Delayed	C: 110 teachers	TY1: 110 teachers	TY2: 110 teachers	--	
2	Immediate	--		TY1: 110 teachers	TY2: 110 teachers	--
	Delayed	--		C: 110 teachers	TY1: 110 teachers	TY2: 110 teachers

D.2. The extent to which the evaluation will provide guidance about effective strategies suitable for replication or testing in other settings.

The external evaluation will provide evidence to support ARCS' proposed blended learning model's ability to increase participating teachers' content and pedagogical knowledge and self-efficacy for teaching new, challenging content in an integrative manner. The evaluation will also gather data to inform the microcredentialing process which Virginia hopes to expand to other areas to support licensure endorsement and provide evidence of highly qualified teachers. Finally, the evaluation will investigate the extent to which the project activities extend to the student level to better prepare students for rigorous secondary-level coursework.

D.3. The extent to which the evaluation will provide valid and reliable data on Relevant Outcomes.

To answer the evaluation confirmatory and exploratory questions, we will administer a variety of measures, including a teacher survey, student performance assessment, and student affective survey.

[3] Teacher *n* was reduced by 10%, student *n* by 50%.

Teacher and school demographic data that may be used as covariates in impact analyses will be gathered on the teacher survey or obtained from the publically available VDOE Fall Membership database.

CS Teacher Survey. This instrument will be developed in collaboration with the ARCS implementation team and tested to assess internal consistency reliability and to establish validity. The survey will include items designed to capture teachers' computer science content and pedagogical knowledge, self-efficacy for teaching integrative computer science, and perceptions of the quality of the PD and resources provided through the program. A number of existing valid and reliable measures will help inform the development of this survey, including the Computer Science Attitudes and Identity Survey (CSAIS; Washington, Grays, & Dasmohapatra, 2016) and the Computing Attitudes Survey (CAS; Dorn & Tew, 2015). The **CS Teacher Survey** will be administered four times: before the first summer institute to establish baseline measures of each construct, just following the first summer institute, at the end of the school year, and again at the end of the second summer institute. The instrument will be administered to control teachers at the beginning and end of the school year, with the end-of -year score summed into composite scores for CS content knowledge, CS pedagogical knowledge, and CS self-efficacy for analysis. Descriptive findings from other survey items will be used for the formative evaluation and fidelity of implementation analyses as described in sections B.3 and D.4. Qualitative data gathered through open-ended survey items will be coded using thematic data analysis (Braun & Clarke, 2006) through Dedoose™ software, which allows for simple code frequency generation and comparison of coding across multiple coders and will also inform formative evaluation efforts.

A modified version of the **CS Teacher Survey** will be administered three times to treatment teachers during the school year between summer institutes to answer the exploratory question regarding the progression of integrated instruction. This survey will ask them to report on the topics taught (e.g., algorithms and programming, data and data analysis, networks) during the respective time interval and the frequency with which they teach integrative lessons. Composite scores will be summed for analysis.

Student CS Content Knowledge Performance Assessment. Grade three, four, and five students of participating teachers will complete a state-developed computer science performance assessment each year. These performance assessments will be developed by VDOE STEM education and assessment personnel and will be scored using a detailed rubric that is aligned with the content and objective of the lesson. This assessment will measure students' knowledge and understanding of integrative computer science as they analyze and solve complex problems. Participating teachers will score the performance assessments, with the evaluation team scoring a select sample of assessments for reliability purposes. The student performance assessment will be administered near the beginning and end of each school year for participating classrooms, with the end-of-year score used as the outcome variable.

Student CS Affect Survey. Students will also complete a measure of attitudes toward computer science and self-efficacy toward computational thinking utilizing items from existing validated instruments including the Computing Attitudes Survey (CAS), Computer Science Attitudes and Identity Survey (CSAIS), Computational Thinking Self-Efficacy Survey, and Student Attitudes toward STEM (S-STEM) survey (Dorn & Tew, 2015; Unfried, Faber, Stanhope, & Wiebe, 2015; Washington, Grays, & Dasmohapatra, 2016; Weese & Feldhausen, 2017). Items will be adapted to language appropriate for elementary students, and the evaluators will establish test-retest reliability, internal consistency, and support for face and content validity. A baseline measure will be obtained at the beginning of the year, with responses from the end-of-year administration summed into composite scores for analysis.

Confirmatory Analyses. Our confirmatory analyses will focus on five primary research questions regarding improvements in teacher's knowledge, pedagogy, self-efficacy, and students' knowledge and affect. In keeping with the WWC review protocols, we will report balance statistics of all baseline teacher- and student-level covariates, and sample attrition at both the teacher- and student-levels. We expect attrition rates to be low due to the mandated implementation of computer science standards by the VDOE, but we will apply the attrition standards established by the WWC to assess bias attributed to participant loss. Missing data will be treated following guidance from the WWC.

We will estimate treatment impacts on all teacher outcomes at the individual level at the end of the two-year program. Our analytic model will include an indicator for treatment status, measures of teacher-level covariates (e.g., years of experience, pretest scores, etc.) as well as fixed effects for cohort. This will allow us to estimate the average overall effect of ARCS on teacher outcomes across all years. The outcome or dependent variables will be the computer science content knowledge, pedagogical knowledge, and self-efficacy composite scores derived from the CS Teacher Survey.

We will also estimate the effects of ARCS on students' computer science content knowledge as measured by the student performance assessment, and affect related to computer science. Given the nesting of students within participating teachers' classrooms, we will perform our impact evaluation within a multilevel modeling framework. Our student-level, or Level 1 model, we will include a control for students' pretest scores with the Level 2 model including an indicator for treatment status. Where available, we will include classroom-level covariates such as teacher experience, class size, and demographic composition to improve our precision. The outcome or dependent variable will be the composite scores derived from the CS Student Affect Survey.

Exploratory Analyses. In addition to our questions regarding the impact of ARCS on teacher and student outcomes, our research design will also allow us to understand teacher completion rates for and perceptions of the microcredentialing process as well as how teacher integrative instruction has changed over the course of the two-year program. We will examine responses to the **CS Teacher Survey** to answer these questions along with microcredentialing completion data from ODU/VDOE. We will apply a non-experimental, descriptive approach to answer the three exploratory evaluation questions and apply the findings to the formative evaluation and fidelity of implementation components as appropriate.

D.4. The extent to which the evaluation plan clearly articulates the key project components, mediators, and outcomes, as well as a measurable threshold for acceptable implementation.

The evaluation of *implementation fidelity* of the ARCS project is designed to provide *frequent formative feedback* to provide the implementation team opportunities to improve ARCS *and annual* *summative results* in the form of reports to the Project Director regarding implementation fidelity. Reports will focus on identifying trends and patterns of implementation, implementation challenges, and perceptions of participants in meeting stated project goals (see section B.3). Implementation fidelity will be measured through program adherence, dosage, quality, and participant responsiveness (e.g., Carroll et al., 2007). The following research questions will be answered in the evaluation of implementation fidelity: (1) To what extent does the ARCS PD align with the project goals? How might alignment be improved? (2) How do facilitators implement the ARCS PD? (3) How engaged are teachers in program activities?; and (4) What are teacher perceptions of ARCS PD experiences?

In addition to implementation-related items on the **CS Teacher Surveys,** evaluators will examine implementation fidelity through PD observations, PD attendance data, and interviews with teachers and program facilitators. Evaluators will observe two consecutive days of the PD each summer, and interviews will be conducted with a subset of teachers and facilitators the spring of each year of the project. Interview responses will support the evaluation of ARCS by identifying effective/ineffective elements that challenge or facilitate implementation of the program. The use of these multiple methods strengthens the evaluation design by allowing evaluators to triangulate findings from qualitative and quantitative implementation data sources, providing a more comprehensive understanding of program implementation than can be obtained through either method alone (Bazeley, 2013; Creswell & Plano Clark, 2007; Dusenbury, Branningan, Falco, & Hansen, 2003; Patton, 2002).

Acceptable implementation will be measured through completion of each of the project components. Participation in the summer PD institutes, web-assisted PD, and the NIC will be mediated through attendance and participation data; attainment of microcredentials will be mediated through enrollment and completion data maintained by ODU/VDOE; development of integrative lessons and resources will be mediated through submission of materials for review and distribution to participants; and CS-integrated lesson implementation will be mediated through teacher responses on the **CS Teacher Survey** at seven administration points throughout the two-year project.