Coding as Another Language: The Development and Implementation of a Computational Thinking Curriculum and Sustainable Professional Development Model in K-2

Response to EIR Priorities: Absolute Priority 1 (Demonstrates a Rationale) and Priority 3 (Field-Initiated innovations--Promoting Science, Technology, Engineering, or Math (STEM) Education, With a Particular Focus on Computer Science

Competitive Preference Priority This project addressees the Competitive Preference Priority: "Projects designed to improve student achievement or other educational outcomes in computer science by expanding access to and participation in computer science coursework for traditionally underrepresented students such as racial or ethnic minorities, women, and low-income individuals." Resulting from the project will be an integrated K-2 computer science curriculum, and its associated teaching materials and professional development strategies that can be used to sustain the work after grant completion and to scale to other states.

Coding as Another Language: The Development and Implementation of a Computational Thinking Curriculum and Sustainable Professional Development Model in K-2

A. Significance

A1. Potential contribution

This proposal involves a partnership between the DevTech research group at Tufts University, co-developer of the free ScratchJr programming language, and Norfolk Public Schools (NPS) in Virginia, to address Absolute Priority 1 (Demonstrates a Rationale) and Priority 3 (Field-Initiated innovations--Promoting Science, Technology, Engineering, or Math (STEM) Education, with a Particular Focus on Computer Science.

Through this partnership, the project will accomplish three goals: 1) create a comprehensive, field tested, high quality integrated K-2 computer science (CS) curriculum and suite of teaching materials and implementation supports that will be free and publically available; 2) achieve high fidelity implementation in schools resulting in statistically significant student learning outcomes and teacher's pedagogical and content knowledge to implement the curriculum; and 3) build capacity of leaders, technology coordinators and specialized coaches to replicate and sustain work following the grant period.

Currently, Virginia is the first state to introduce K-12 CS Standards of Learning (Virginia Department of Education, 2017). However, as both Virginia and other states implement policies, there is a need of developmentally appropriate research-based curriculum as well as rigorous research-based professional development models that can scale up in the K-2 segment. To address the first need, given that ScratchJr is a free programming language designed for that age segment (Resnick & Bers, 2015), and that is widely used with over 3.9 million downloads a year, the proposed project aims to develop a K-2 CS curriculum, called "Coding as Another Language" (CAL), that integrates math and literacy while engaging children in learning to code with ScratchJr and unplugged activities to promote computational thinking. To address the second need, the proposed project seeks to develop and field test professional development strategies that are scalable for implementing the CAL curriculum and that are supported by evidence of learning outcomes.

The collaboration with NPS provides an opportunity to work with a socioeconomically and racially diverse population. Norfolk struggles with poverty, high mobility, and schools that have lost accreditation. In addition, it has one of the highest concentrations of military-connected students in the nation. NPS ranks among the lowest performing school divisions in Virginia and includes 32 elementary schools. The student population is 22.04% Caucasian, 60.91% Black, 7.95% Hispanic, 2.22% Asian, .35% Hawaiian/Pacific Islander, .44% American Indian/Alaska Native, and 6.10% multi-race. Currently 70.6% of the students are economically disadvantaged. The graduation rate in NPS is 78.9% while the rate in Virginia is nearly 90%.

NPS has already shown a commitment to CS education. In 2016, the district was awarded a $1.5-million-dollar grant, "Operation: Break the Code to College and Career Readiness", to support military dependent students and enhance academic achievement through integrated computer science. In this context, a collaboration with the DevTech research group at Tufts University started. The proposed project builds on this early work by seeking to have an impact for *all* children in the district by significantly increasing K-2 CS content knowledge and providing scalable strategies for introducing CS in communities with high need students.

A2. Promising new strategies

In the automated economy, computer programming is essential across diverse disciplines. Occupations that value programming skills provide as much as 20% of "career-track" job openings (Burning Glass Technologies, 2016), and the number of jobs in information technology will grow 12.5% from 2014 to 2024 (Fayer, Lacey, & Watson, 2017). To meet this growing need, there has been an increase in new educational policies and frameworks at the federal and state level to prepare K-12 students for CS related professions.

However, while most of the educational implementation and research is happening in late elementary, middle school, high school and college (Guzdial, 2008; Wilson, Sudol, Stephenson & Stehlik, 2010), the frameworks, standards and best practices mandate to start in kindergarten (Barron et al., 2011;

International Society for Technology in Education, 2007; NAEYC and Fred Rogers Center for Early Learning and Children's Media, 2012; U.S. Department of Education, 2010; White House, 2016; U.S. Department of Education & U.S. Department of Health and Human Services, 2016; Paciga & Donohue, 2017).

There are both economic and developmental reasons for the choice to start early. Research shows that educational interventions that begin in early childhood are associated with lower costs and more durable effects than interventions that begin later on (e.g., Cunha & Heckman, 2007; Heckman & Masterov, 2007). Two National Research Council reports—*Eager to Learn* (2001) and *From Neurons to Neighborhoods* (2002) detail the importance of early experiences for later school achievement. Furthermore, research shows how children who are exposed to STEM curriculum at an early age demonstrate fewer gender-based stereotypes regarding STEM careers, increased interest in engineering and computer science (Sullivan & Bers, 2018; Metz, 2007; Steele, 1997) and fewer obstacles entering these fields later in life (Madill et al., 2007; Markert, 1996). Research also suggests that for addressing the under-representation of women in CS, it is critical to improve early education (Varma, 2009).

However, if CS education is to start in the early years, when children are just starting to develop literacy and numeracy skills as well as learn "schooling", there is a need for pedagogical approaches, curriculum and programming languages that are developmentally appropriate for young children (Bers, 2018). The need to fulfill the work-pipeline is not enough of a rationale for the introduction of CS in early childhood education and thus it must be integrated with foundation content areas such as math and literacy. If we are going to start CS education in kindergarten the rationale shouldn't be the creation of the future workforce, but the future citizenry.

The proposed work is grounded on Bers's previous work that understands "Coding as a new literacy" (Bers, 2018). Within this framework, those who learn how to code from a young age, will not only be able to participate in the automated economy, but will also have a civic voice. As children learn how to code, they also develop their creativity to grow a society of innovators (Resnick, 2018) who can think in new ways. (Papert, 1980).

Researchers have coined the term "computational thinking" to refer to an analytical process rooted in the discipline of CS. It involves thinking recursively, applying abstraction, breaking up a complex problem in smaller tasks, and using heuristic reasoning to discover a solution (Wing, 2006; 2011). There is debate whether computational thinking can be classified as a unique category of thought (Gadanidis, 2017; Pei, Weintrop, & Wilensky, 2018). However, the term has grown popular at a time when schools are incorporating CS in massive ways and developing frameworks (K–12 Computer Science Framework Steering Committee, 2016). While computational thinking is not the same as coding, the act of coding can facilitate the spread of computational thinking. The proposed project will address the teaching of computational thinking through both unplugged activities and on-screen coding with ScratchJr, integrated with other content areas, in particular math and literacy, in the K-2 segment.

Computer programming initiatives are growing in popularity amongst early childhood researchers and educators (Bers, 2008; Bers, Seddighin, & Sullivan, 2013; Sullivan & Bers, 2015; Elkin, Sullivan, & Bers, 2014; Kazakoff & Bers, 2014; Bers, 2018; Hallström, Elvstrand & Hellberg, 2015; Werner, Denner, & Campe, 2014). However, despite their popularity and new policies, the US still lags behind other countries (Code.org, 2019). Virginia is the first state to mandate the teaching of CS starting in kindergarten. Thus, the proposed project comes in a timely manner and can serve as a demonstration site for other states considering their options.

The push for CS education in the US has grown in conjunction with the STEM (Science, Technology, Engineering, Mathematics) education movement in the 1950's during the height of the Space Race. But it was the creation of the LOGO computer language by Papert, Feurzeig and colleagues in 1967 that is generally described as the beginning of CS education in elementary schools (Blikstein, 2018).

LOGO was the first widely disseminated programming language designed for children (Papert, 1980). Although LOGO became popular for supporting new ways of thinking about math (Abelson & DiSessa, 1982; Clements & Sarama, 1997), Papert's intent went beyond math (Bers, 2008). Papert wanted children to learn to think in new ways about all subjects and, most importantly, about the nature of thinking itself. Thus, he believed the teaching of LOGO ought not to be limited to CS classes, but integrated into every class. However, for that vision to come true, there is a need of professional development and integrated curriculum. The proposed project addresses this.

Although thousands of teachers created community networks and curricula for LOGO (Papert, 1987, The Logo Foundation, 2015), and research slowly embarked on understanding its impact (Feurzeig & Lukas, 1972; Milner, 1973; Kull, 1985; Clements, 1985) there was not a concerted effort. A large-scale study showed that children using LOGO in grades K-6 scored significantly higher on tests of mathematics, reasoning, and problem-solving (Clements et al., 2001), and children who used LOGO in kindergarten were also found to have sustained attention, self-direction, and took pleasure in discovery (Clements 1987). However, not all results were positive (Pea, 1983; Clements & Meredith, 1993).

In addition to LOGO, research with other programming environments was conducted and a meta-analysis of 65 studies revealed that students who participated in computer programming typically score higher on various cognitive-ability assessments (Liao and Bright 1991). While most of this research was not focused on early childhood, a series of pilot studies with preschoolers and kindergarteners showed that coding can significantly improve sequencing ability- an important pre-math and pre-literacy skill (Kazakoff, Sullivan, & Bers, 2013; Kazakoff & Bers, 2014).

As time went by, new programming languages inspired by LOGO and Papert's Constructionism (Kafai, 2006; Kafai, 2018), such as Scratch (Resnick et al, 2009), designed for children 8 and up, grew in popularity (Lifelong Kindergarten Group at MIT Media Lab, 2019). However, the development of new programming languages has traditionally come at a faster rate than the implementation of studies to evaluate their impact (Stanton et. al, 2016). The proposed project seeks to address this gap in the K-2 segment by using ScratchJr, which is inspired by Scratch and LOGO, but targets younger children.

ScratchJr is the first programming language explicitly designed for young children, 5 to 7, which meets their developmental needs. ScratchJr is the result of a long-lasting collaboration between the DevTech Research Group at Tufts University and the MIT Lifelong Kindergarten Group funded by the National Science Foundation and the Scratch Foundation (Bers & Resnick, 2015).

ScratchJr enables children to create interactive stories and games by snapping together graphical programming blocks to make characters move, jump, dance, and sing. Through ScratchJr young children learn how to code and how to engage in computational thinking while creating meaningful projects. Since its launch in 2014, ScratchJr has been downloaded 10.3 million times and has actively been used in every country (except North Korea). It can be freely downloaded to iPads, Android tablets, Kindle tablets and Chromebooks and it has been translated to Spanish as well as a dozen other languages.

The ScratchJr team began collecting analytics data in 2016. Since then, as of March 2019, over 37 million projects have been created, and existing projects have been edited over 49 million times, indicating that users are improving and debugging their projects over time. Additionally, over 1.15 million projects have been shared with others. ScratchJr maintains a rate of 429,000 returning users each month, while still bringing in a consistent rate of 323,000 new users each month. The DevTech group has developed curricula and teaching materials to integrate ScratchJr with other content area in early childhood in both formal and informal learning settings, homes and schools. Three twenty-hour curriculum units have been developed to accompany the ScratchJr app: *Animated Genres, Playground Games* and *Reinforcing Common Core*. In addition, several activities were developed in the form of coding cards (Bers & Sullivan, 2018) as well as the Coding as Literacy (CAL) curriculum to support literacy integration (See Appendix I). The proposed project will build on previous work and the CAL curriculum by also incorporating math, low-tech materials and unplugged games to address powerful computational ideas, skills, and habits of mind that promote computational thinking.

Pilot studies found that children in K-2 can master ScratchJr, which in turn supports learning of problem solving, foundational programming, and discipline-specific content in math and literacy (Flannery et al., 2013). Combined pilot work representing a total sample of N = 333 children (aged 5-7 years) reveal that children used ScratchJr to make creative projects, which supported literacy practices of exploring and utilizing narrative structures, decoding symbols, and reading and writing digital media. (Flannery et al., 2013; Portelance & Bers, 2015). Further, pilot work demonstrates that ScratchJr can support learning outcomes when educators have diverse teaching approaches, although positive learning outcomes are more pronounced when the learning is child-directed and open-ended (Strawhacker, Lee, & Bers, 2017).

Despite programming becoming popular and ScratchJr and its resources being widely utilized, there is a lack of well-researched, evidence-based integrated early childhood CS curriculum and professional development strategies. Technology and pedagogy are not the same thing. As new programming languages that are developmentally appropriate emerge and are widely used, such as ScratchJr, there is a need to conceptualize pedagogical approaches for teaching CS in the early years. These approaches must be consistent with developmentally appropriate practice (Bredekamp, S, 1987) and must embrace the maturational stages of children by inviting play and discovery, socialization and creativity (Bers, 2018). This proposal seeks to address this need for developing sustainable and scalable integrated curriculum and professional development strategies replicable for all children.

The DevTech group’s unique expertise that led to the design and development of ScratchJr and a suite of teaching materials and professional development strategies, as well as pilot impact studies, is well-positioned to conduct the proposed project that will meet What Works Clearinghouse standards. The partner in this project, NPS (see Appendix C) is well-positioned to implement this study since Virginia is the first state to introduce K-12 CS Standards (Virginia Department of Education, 2017), and there is a strong pre-existing collaboration between NPS and DevTech.

The proposed project will involve all 32 schools in the district and accomplish three goals: 1) create a comprehensive, field tested, high quality K-2 integrated CS curriculum and suite of teaching materials and implementation supports that will be free and publically available. This will be based on pilot curriculum that has being tested by literacy integration (see Appendix I). The new curriculum, with integration with both literacy and math, will be developed and field-tested in 2 schools; 2) achieve high fidelity implementation in the district in 15 schools (group 1) to evaluate if there are statistically significant increases in student learning outcomes and teacher's pedagogical and content knowledge; 3) build capacity of school leaders, technology coordinators and CS coaches to replicate the work in other 15 schools (group 2) and sustain work following grant period so the model can scale up.

B. Quality of the Project Design

B.1 Goals, objectives, and outcomes

This proposal builds on previous work by Prof. Bers and her DevTech research group, co-developers of ScratchJr and associated curricular materials and pedagogical approaches, and the previously established collaboration with NPS. Through a partnership between Prof. Bers, the DevTech research group and NPS, a total of 32 schools in the segment K-2 will be involved. The project will accomplish three goals: 1) create a comprehensive, field tested, high quality K-2 computer science (CS) curriculum and suite of teaching materials and implementation supports that will be free and publically available that will be pilot tested in 2 schools; 2) achieve high fidelity implementation in 15 schools in the district (group 1) to evaluate if there are statistically significant increases in student learning outcomes and teacher's pedagogical and content knowledge when compared to schools not participating in the initiative (group 2); 3) build professional capacity to replicate the work in other 15 schools (group 2) and sustain work following grant period. Project goals, objectives and outcomes with associated measures are specified in table 1. Appendix I provides more information on instruments and measures focused on CS.

Table 1: Goals, Objectives, Outcomes and Measures

Objectives	**Outcomes**	**Measures**

Goal 1: create a comprehensive, field tested, high quality K-2 computer science curriculum and suit of teaching materials and implementation supports that will be free and publically available		
1. Curriculum is aligned to standards	Teachers and specialists report that curriculum covers key areas	Surveys, semi-structured interviews and focus groups
2. Pilot testing of draft curriculum and implementation supports in 2 schools (training and 3 tier coaching approach plus on-line ScratchJr Sharing Resources)	Pilot data is collected for each curriculum module Pilot assessments of teachers and student outcomes Data from pilots is used to revise curriculum	Pilot study, surveys and semi-structured interviews
3. Complete curriculum and implementation supports implemented in classrooms in group 1	Teachers and leaders report that complete curriculum meets their needs	Surveys, semi-structured interviews and focus groups
4. Curriculum and implementation supports posted on ScratchJr Sharing Resources website and made publically available	Number of curriculum downloads and website visits as well as ScratchJr analytics data	Website data analytics ScratchJr analytics
5. Curriculum and implementation supports implemented in classrooms in group 2 by Tech leaders.	Teachers and Tech leaders report that complete curriculum meets their needs	Surveys, semi-structured interviews and focus groups
Goal 2: achieve high fidelity implementation in group 1 and 2 to evaluate if there are statistically significant increases in student learning outcomes and teacher's pedagogical and content knowledge		
1. Implementation of curriculum in group 1 and 2	Teachers implement curriculum with fidelity Teachers report competence and confidence teaching curriculum Teachers report technical proficiency with ScratchJr Student outcomes are conducted	FOI indices, surveys, interview, impact study evaluation using Solve-Its assessments and TACTIC, Tech Check, as well as design journal portfolios
2. Support curriculum implementation with integrated professional development	Teachers attend training Teachers participate in tier 1and coaching Teachers access tier 3 coaching ScratchJr Sharing resources website Best practices of teachers in group 1 are shared with group 2	Operations data and surveys, classroom logs, google analytics Pre and post training surveys
Goal 3 build capacity leaders, technology coordinators and CS coaches to replicate the work in group 2 and sustain work following grant period.		
1. Formation of Tech leaders team and support them to	Tech leaders access tools provided to them	Surveys and google analytics

engage in curriculum implementation		
2. Tech leaders enrolls in ECT graduate program at Tufts	Completion of ECT program	Certification
3. Tech leaders train schools in group 2	Fidelity of implementation	Surveys, logs, data
4. Tech leaders develop strategy for sustained work aligned with district	Development of strategic plan	Focus groups and interviews, final strategic plan

B2. Conceptual framework underlying the proposed research

The driving rationale behind this proposal is the logic model in Appendix G. In summary, to improve student learning, teachers need 1) a developmentally appropriate research-based integrated CS curriculum, combined with 2) comprehensive, multiple, and ongoing forms of professional development to support implementation fidelity. Below is an examination of the underpinning research base that substantiates this rationale. A well-implemented, developmentally appropriate curriculum is a critical factor in student academic success (Workman & Ullrich, 2017; Atchison, Diffy, & Parker, 2018). However, the curriculum must be *high-quality* (NCQTL, 2015).While there are numerous quality frameworks, The National Center on Quality Teaching and Learning (NCQTL) identifies 13 components that need to be present in an effective curriculum (NCQTL, 2015): 1. Grounded in child development principles; 2. Evidence-based; 3. Shows effects on child outcomes; 4. Comprehensive across learning domains; 5. Depth for each covered learning domain; 6. State Specific learning goals; 7. Well-designed learning activities; 8. Responsive teaching; 9. Supports for individualized instruction; 10. Culturally and linguistically responsive; 11. Ongoing assessments; 12. Professional development opportunities; and 13. Family involvement materials.

To date, no comprehensive, integrated CS curriculum for K-2 demonstrates evidence of each of the components. As districts are moving forward with mandating the teaching of CS, it is imperative to engage in the work proposed here so to produce high quality curriculum that adheres to each of the NCQTL components. The proposed curriculum builds on both DevTech's previously developed pilot units (Bers, 2018), is inspired by diverse frameworks (Google for Education, 2010; Brennan & Resnick, 2012), and will be aligned with the K-12 CS Framework (K-12 CS Framework Steering Committee, 2016) and the Standards for Technological Literacy; International Technology and Engineering Education Association, 2007), as well as Common Core Frameworks for Math and Literacy (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), and Virginia Department of Education's Standards of Learning for English and Standards of Learning for CS (Virginia Department of Education, 2017).

The curriculum will be organized around powerful ideas that are fundamental to computational thinking and, at the same time, are developmentally appropriate for young children. Each powerful idea is defined and explored at a different level of depth, in a spiral manner, in the sequence of K-2. For example, understanding algorithmic thinking in K will focus on sequencing, while in second grade it will be extended to understanding that within that sequence there are patterns that repeat themselves. For each powerful idea, the materials in each unit will engage young children in developing concepts, skills and habits of mind by using ScratchJr as well as participating in unplugged games and activities.

The curriculum will meet the following principles: 1) flexible project-based units that introduce coding and computational thinking in a playful, developmentally appropriate way by integrating powerful ideas of computer science with math and literacy skills; 2) strengthened social-emotional aspects by not only focusing on the cognitive dimension of computer science, such as problem solving, but also habits of mind such as perseverance; 3) the format and content of activities explicitly designed to be attractive to girls and marginalized populations (Fisher & Margolis, 2002; Richmond, 2000; Rosser, 1990; Sadler, Coyle, & Schwartz, 2000; Tobin, Roth, & Zimmerman, 2001), as well as meet the needs of gifted or special education students by being adaptable and personalized (O'Conner, 2000).

Having a high-quality curriculum is essential for success, but it must be implemented well to achieve impact (Hamre et al., 2010; Wasik, Bond, & Hindman, 2006). One-time professional development workshops are not enough for changing practices and improving student's learning outcomes (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007; Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). In contrast, research shows that coaching is effective for improving practice because it enables continuous understanding, interpretation, and application of new strategies (Parkinson, Salinger, Meakin, Smith, & Drummond, 2018; Elish-Piper & L'Allier, 2011; Taylor, Pearson, Peters, & Rodriguez, 2005). However, these findings are moderated by the quality of the coaches who can align their work with classroom curriculum (O'Keefe, 2017, Parkinson, Salinger, Meakin, Smith, & Drummond, 2018; Elish-Piper & L'Allier, 2011; Taylor, Pearson, Peterson, & Rodriguez, 2005).

The proposed project will provide integrated professional development that includes both training and coaching that fits within the structure of a K-2 program, as well as an approach for assuring sustainable coaching quality by providing graduate level training to a selected leadership group that targets the complex network of adults in charge of teaching CS in early childhood. This includes, regular classroom teachers, technology coordinators and integrators, and specialized coaches. The following strategies will be utilized: 1) <u>Trainings</u>: Full-day seminars to understand the developmental underpinnings, the scope and sequence of the CS curriculum, the points of alignment and integration with other disciplinary content and skills, the adaptations that can be made to better suit the population needs, and the embedded student's assessments within the curriculum. 2) <u>On-going three-tiered coaching</u>: Tier 1 involves embedded on-site coaching. Tier 2 involves individualized online virtual coaching sessions. Tier 3 involves participation in the ScratchJr Sharing on-line network. Teachers will receive a weekly email to alert them of new learning opportunities and video case studies aligned with the curriculum, and will be able to sign up for individualized targeted on-line tutoring sessions. 3) <u>Graduate certification</u>: NPS will select a diverse group of 20 Tech leaders that will be involved in the integration and teaching of CS in K-2. That is teachers, specialized coaches and technology coordinators and integrators. In addition to participate in training conducted by the DevTech research group, Tech Leaders will enroll in the Early Childhood Technology (ECT) graduate program at Tufts University which blends on-online courses with one-week intensive summer supervised practicum at the lab school: the Eliot Pearson Children's School. A gradual-release model will be utilized. During Year 2, DevTech will train and coach group 1 along with Tech leaders. Later on, during Year 3 and 4, Tech leaders will train and coach group 2. A critical outcome is to ensure that Tech leaders have the capacity and resources needed to on-board new teachers while effectively supporting returning ones.

B3. Adequacy for ensuring feedback and continuous improvement

Both the curriculum development and the professional development will undergo several phases that integrate research-based content and field-based practice.

Curriculum Development:

Draft phase: Based on previous work by DevTech, as well as a matrix of Virginia's early childhood learning standards in math and literacy and CS learning standards, a scope and sequence of K-2 integrated curriculum will be developed in consultation with experts to ensure that the curriculum can be used by every student in the district and fully integrated (see Appendix B). Resulting from this work, a complete draft of the curriculum will be developed, including unplugged low-tech activities and coding projects with ScratchJr. The draft will undergo a review and refinement process. Once the review is complete, a Program Guide to help launch the new curriculum will be developed, as well as on-line resources for supporting family engagement. Details of the development process and timelines are found in Section C.

Pilot phase: The team will work with 2 schools that will be selected based on their willingness to serve as pilot sites. Schools will be selected to represent a range of experiences and backgrounds to ensure the curriculum and supports meet the needs of a diverse work force. Schools that participate in the piloting will not be placed in the pool to be assigned to the implementation study. Through classroom observations, focus groups, and interviews, data will be collected and analyzed to address the following questions: What do teachers find useful? What engages the children? What supports are essential? What are the implementation barriers? Observations will include: timing and pacing of the lessons; teacher-child interactions; modifications made (both planned and impromptu); children's engagement; use of materials; children's development of computational thinking; resulting ScratchJr projects.

Structured case studies built around particularly challenging CS concepts will be constructed, shared and discussed. Based on this pilot, the draft will be revised and the final curriculum will be developed.

Final curriculum: The development process will not be linear; rather, areas that were refined will go back to the pilot phase to ensure revisions achieve the intended result. The final curriculum will be implemented in 30 schools (15 schools assigned to group 1 and 15 schools to group 2). Student learning outcomes will be collected including CS learning outcomes (both computational thinking unplugged through our TACTIC instrument; and ScratchJr coding knowledge through Solve-Its embedded in the curriculum); as well as literacy and math scores. See Appendix I. Teachers will also be assessed to understand the impact of the professional development.

Professional Development

Formation and training of Tech leaders team: A leadership team will be formed with 20 selected members chosen from NPS coding coaches, and CS specialists and leaders will provide feedback during curriculum development and pilot testing. In addition, the Tech leader team will participate in all trainings for schools in group 1, providing feedback and modifications. Tech leaders will also be enrolled in the blended on-line ECT graduate program at Tufts University.

Training for Group 1: The training for group 1 will be led by the DevTech team, with the support of the Tech leader team, which will be tasked to provide feedback and modifications, which will be reflected in their implementation for schools in group 2 the following year.

Training for Group 2: The training for group 2 will be led by the Tech leader team, with supervision by the DevTech team, that will mainly focus on documentation for dissemination of best practices through the ScratchJr Sharing resources website.

C. Adequacy of Resources and Quality of the Management Plan

C1. Adequacy of the management plan: responsibilities, timelines, and milestones

The management plan involves the close working relationship between three groups: 1) The DevTech research group, which has over 20 years of experience with early childhood technologies, both designing new programming languages, such as ScratchJr and KIBO robotics, and its associated curriculum materials and professional development strategies, as well as conducting studies to evaluate impact. The team includes graduate students, post-docs, undergraduates and staff members. Prof. Bers, who heads the DevTech research group, is a professor in both the Eliot-Pearson Dept. of Child Study and Human Development and the Computer Science Dept. at Tufts University, as well as Director of the graduate ECT program. She is a leader in the field of early childhood CS and has received and managed multiple grants totaling over $10 million, as well as directed complex, interdisciplinary teams and deployed projects all over the world; 2) The NPS team will be led by Angela de Mik, who has experience with the leadership and management of a $1.5 million DoDEA grant in elementary CS education. She served on the 2017 CodeVA Coaching Cohort and was an appointee to the Virginia Department of Education CS Framework Committee; and 3) the external evaluation team, will be led by program evaluator, Patricia Moore Shaffer, Ph.D., who has served as the lead evaluator for two NSF Robert Noyce Teacher Scholarship Program grants and led numerous evaluation studies of K-12 STEM professional development initiatives. She is the former evaluation manager for NASA's Office of Education (2011-2015). Together this team (see Appendix B) is well-positioned to carry out this project on time and on budget.

Below are the timelines and milestones for each objective, followed by a description of the teams responsible for accomplishing all tasks, for each of the objectives. See Table 2. (Note: Team abbreviations are: **PL:** Project leadership team; **CP**: Content production team; **PD**: Professional development; **FO**: Field Operation team; **RE**: Research and evaluation; **EE**: External Evaluation.)

Table 2

Goal 1

Create a comprehensive, field tested, high quality K-2 computer science (CS) curriculum and suite of teaching materials and implementation supports that will be free and publicly available

Objectives	Activities	Measures	Start Date	End Date	Resp. Person
Curriculum is aligned to standards	Completion of draft curriculum and supporting materials	Draft Curriculum and supporting materials	Fall 2019	Spring 2020	PL, CP RE
Pilot testing of draft curriculum and implementation supports in 2 schools (training and 3 tier coaching approach plus on-line ScratchJr Sharing Resources)	Development of evaluation plan	Evaluation plan	Fall 2019	Fall 2019	RE
	Development of focus groups, semi-structured interviews protocols, and surveys	Research Protocols	Fall 2019	Fall 2019	RE, EE
	Prepare and submit IRB application	IRB approval	Fall 2019	Fall 2019	RE
	Pilot study conducted in 2 schools	Surveys and semi-structed interviews	Spring 2020	Spring 2020	PD, FO
Complete curriculum and implementation supports in classrooms in group 1	Analyze data resulting from student and teacher's assessments and focus groups and interviews.	Surveys, semi-structured interviews, Pre and Post data surveys	Spring 2020	Spring 2020	PL, RE, EE
	Revise all curriculum materials and supporting documents	Revised curriculum and materials	Spring 2020	Spring 2021	PL, CP, RE
Curriculum and implementation supports posted on ScratchJr Sharing Resources website and made publicly available	Develop ScratchJr resources website and analytics engine	SractchJr Sharing Resources website	Spring 2020	Spring 2020	CP
	Curriculum and all resources posted on-line	Track analytics data such as number of curriculum downloads	Spring 2020	Spring 2021	CP

Goal 2

Achieve high fidelity implementation in group 1 and 2 to evaluate if there are statistically significant increases in student learning outcomes and teacher's pedagogical and content knowledge

Objectives	Activities	Measures	Start Date	End Date	Resp. Person
Implementation of curriculum in group 1 and 2	Implementation of Curriculum Group 1	FOI indices, surveys, interviews; impact study evaluation; literacy and technology outcomes (see table 4)	Fall 2021	Fall 2021	PL, PD, FO, RE, EE
	Implementation of Curriculum Group 2	FOI indices, surveys, interviews, impact study measures (see table 4)	Fall 2022	Fall 2022	PL, FO, EE
Support curriculum implementation with integrated professional development	Professional Development Group 1	Operations data and surveys, google analytics, surveys and logs	Spring 2020	Spring 2020	PD, FO, RE
	Data Analysis Group 1 and Group 2	Operations data and surveys, google analytics,	Spring 2020	Fall 2021,	PL, RE, EE

		surveys and logs		Spring 2022, Fall 2022, Spring 2023	

Goal 3 Build capacity of principals, school leaders, technology coordinators and coaches to replicate the work in schools in group 2 and sustain work following grant period					
Formation of Tech Leaders team to engage in curriculum implementation	Support curriculum implementation with professional development for PLC leaders	Surveys, interviews	Fall 2020	Fall 2020 Spring 2021, Fall 2021	FO, PD, RE, EE
Tech Leaders enroll in ECT graduate program	PLC Leader enroll in ECT Program	Certification from Tufts University	Fall 2020	Fall 2020	FO, PD
Tech Leaders develop strategy for sustained work aligned with district	PLC leader and superintendents develop strategy for sustained work	Focus groups and interviews	Fall 2020	Fall 2022, Spring 2023	PL, FO
	Provide evaluation findings and feedback biannually	Focus groups and interviews, lesson logs	Fall 2020	Spring 2023	EE
	Convene technical advisory group	Focus groups and interviews, final plan	Spring 2020, 2021, 2022, 2023	Spring 2020, 2021, 2022, 2023	EE, PA
	Complete impact evaluation study and share results	Study results		Spring 2023	EE

C2. Qualifications of key project personnel

DevTech team: **Prof. Marina Bers** will oversee all aspects of the project. Prof. Bers has devoted her academic career to promote the development of computational thinking and coding for early childhood education. With NSF funding, Bers has developed and studied two early childhood technologies that are widely available: the ScratchJr programming language, in collaboration with the MIT Media Lab (NSF DRL-1118664); and the KIBO robotic system that uses tangible blocks and no screens (NSF DRL-1118897; NSF DRL-0735657), commercialized by KinderLab Robotics through NSF SBIR funding Phase I, IB and II (NSF SBIR 1456530). Previous NSF funding (Career IIS-0447166) allowed Bers to develop a theoretical framework, Positive Technological Development (PTD), for designing technology-rich integrative curricular experiences (Bers, 2006; 2012; 2018).**Dr. Ziva Hassenfeld**, a postdoctoral fellow with a PhD from Stanford's School of Education, will coordinate professional development and coaching**. Anne Drescher**, ScratchJr project manager will work on all aspects of creating on-line resources and the ScratchJr sharing website. **Dr. Laura DeRuiter** will work and supervise data collection and analysis and bring her expertise on methodology. (See appendix B). A **doctoral student** will conduct research producing thesis and academic publication. A **team of undergrads** will support and work on different aspects of the project. In addition, a **project manager** will be hired to serve as primary liaison with NPS and the evaluation team.

NPS Team: **Angela R. de Mik,** M.S. will serve as Project Coordinator and the interface with the DevTech team. She has a strong background in CS education as well as curriculum and instruction experience working with NPS. **Dr. Michael Cataldo**, Executive Director of Curriculum & Instruction in NPS, will assist with the implementation of CS curriculum and its integration at the elementary level as required by the new state statute. **Dr. Karren Bailey**, Chief of Accountability and Information Officer in the Assessment, Research & Accountability Department works directly for the division Superintendent and will assist with the implementation of PD strategies aligned with the new state statute as well as data collection. **Gwen Collins,** Senior Coordinator of English Instruction, and **Rhonda White**, Senior Coordinator of Math Instruction will select, support and assist the formation of the Tech Leaders team.

External evaluation team: Led by **Patricia Moore Shaffer**, Ph.D., the Shaffer Evaluation Group (SEG) will monitor project implementation and accomplishment of project goals and objectives (using data collected/analyzed by DevTech); participate in the project leadership team and work with that team; conduct a statistical audit of DevTech data analyses (third-party verification); interpret and report interim study findings on a bi-annual basis to the project leadership team; triangulate results to provide a synthesis report at the conclusion of the project; and convene the external technical advisory group. Team members include evaluation lead Patricia Moore Shaffer, who will lead the external evaluation team, monitor project implementation and accomplishment of project goals and objectives, participate in the project leadership team, interpret and report study findings, produce the synthesis report, and facilitate the technical advisory group; Dr. Jenny Hindman, SEG senior research associate, who will coordinate the external evaluation activities; Noel Williams, SEG research associate and doctoral student, who will provide research assistance; and a contracted statistician, who will audit the data collection and analyses.

In order to conduct work in a timely and collaborative manner, the DevTech team, the NPS team and the External Evaluation team will form six working groups:

1) **Project leadership** (PL) will involve Prof. Bers, Angela R de Mik, Patricia Moore Shaffer and the project manager. This team will meet monthly on-line and tend to all aspects of grant management, ensuring the project is meeting all deadlines within budget. The team will review implementation and student achievement data and will manage high-level district/partner relationships.
2) **Content production** (CP), led by Anne Drescher, will be responsible for producing all of the content (textual, graphical and videos) needed for both the curriculum and the associated teaching materials and the ScratchJr sharing resources network. This group will interface with members of the NPS team, Angela R. de Mik, Dr. Michael Cataldo, Gwen Collins, Dr. Karren Bailey and Rhonda White.
3) **Professional development** (PD), led by Dr. Ziva Hassenfeld, in coordination with Angela R de Mik, will develop all strategies for implementing and deploying the multifaceted professional development approach needed for groups 1 and 2, as well as the Tech Leaders team.
4) **Field operations** (FO), led by Angela R. de Mik will facilitate all work involving the schools, such as coordination and arrangement of all trainings, provision of support materials and resources, management and coordination of data collection process, communication and collaboration with school leadership and teacher support.
5) **Research and evaluation** (RE), co-led by Drs. Laura DeRuiter and Patricia Moore Shaffer, will coordinate and implement the research and evaluation studies associated with this initiative.

6) **Technical Advisory Working Group** (TA), co-facilitated by Patricia Moore Shaffer and Angela de Mik, will consist of project stakeholders, including parents, teachers, school- and state-level educational administrators, and will meet biannually to be briefed and offer feedback on project implementation, and policy implications of study findings.

C3. Potential for continued support

After completion of the project, given that ScratchJr is free, and so will be the resulting curriculum and professional development materials, as well as the on-line ScratchJr Sharing Resources website, any district will be able to access the publicly available information. In addition, the project would have built internal capacity at NPS to continue the work. Furthermore, the Scratch Foundation has been steadily supporting the widespread use of ScratchJr since 2014 and will continue to do so (see Appendix C). This will ensure updates to ScratchJr and bug fixes as new technological platforms might be deployed.

D. Quality of the Project Evaluation

The proposed project will involve all 32 elementary schools in the NPS system: 2 schools will be engaged in pilot testing the CS curriculum and suite of teaching materials and implementation supports; 15 schools (Group 1) will implement with fidelity the pilot-tested curriculum; and 15 schools (Group 2) will replicate the work directed by Tech leaders. NPS student totals are: K (2561), 1st (2585), and 2nd (2359) grade. The study will involve the training of approximately 450 teachers and data collection from a total of about 7,505 students across the pilot study and the project evaluation. The school district has confirmed that: 1) all 32 of its elementary schools will participate in the study, and 2) no schools have previously implemented curriculum using ScratchJr. As discussed in the introduction, DevTech selected this district because of the opportunity to work with a socioeconomically and racially diverse population. Since the pilot study is discussed earlier, this section focuses on the impact study, implementation study, and sustainability study. The timeline for the evaluation is presented below in Table 3.

Table 3 Timeline of studies aligned with school year

Fall 2019	SY19-20 (Year 1)	SY20-21 (Year 2)	SY21-22 (Year 3)	SY22-23 (Year 4)
Curriculum and materials development, field testing in pilot sites (2 schools)		Impact study Group1 (15 schools)	Impact study Group 2 (15 schools)	Data analysis (30 schools)
		Implementation Study		
			Transfer and Sustainability study	

D1. Methods of evaluation and What Works Clearinghouse standards

The evaluation will test the impact of the CS curriculum on students' computational thinking, coding skills, and early language and math skills. The three questions that the **impact study** will answer are: *1) What is the impact of the CS curriculum in K-2 classrooms on student development of computational thinking?, 2) What is the impact of the CS curriculum in K-2 classrooms on student development of coding skills?, and 3) What is the impact of the CS curriculum in K-2 classrooms on student development of early language and math skills?* To answer these questions, the evaluation design will use a randomized control trial design with cluster-level assignment with the school as the intervention unit. The cohort, consisting of Groups 1 and 2 with 15 NPS elementary schools randomly assigned to each group, will be tracked during Intervention Years 2-4. Group 1 will implement the CS curriculum supported by training from the DevTech research group during the first year of implementation and participate in the evaluation study; Tech leaders will also be trained during Year 1. Using a delayed treatment design, Group 2 schools will delay implementation of the intervention until Year 3, allowing Group 2 to function as a control group during the first year of implementation. Group 1 and 2 students will be compared in Year 3 and 4, using three-level hierarchical linear modeling (HLM), controlling for covariates at the student, teacher, and school levels, to test for differences in the following outcomes: computational thinking, coding skills, and early math and language skills.

Assuming a within school year attrition rate of 13% (PCEC, 2008, p.24), we conservatively estimate obtaining pre- and posttest achievement scores for a total of 5,294 students. We anticipate the study will meet WWC criteria for low overall and differential attrition (WWC, 2017), as previous curricula impact studies document low within-year student attrition and no evidence of differential attrition between treatment and control groups (PCEC, 2008). Further, to examine whether the student sample meets the WWC standard for baseline equivalence after attrition, the evaluator will use pre-test student assessment scores to test for a Hedge's g of 0.05, the WWC standard for sample baseline equivalence threshold (WWC, 2017). By accounting for clustering and statistically controlling for group differences, the proposed study designs meet the WWC Standards Evidence Standards with Reservations, providing a moderate level of evidence of the effectiveness of our intervention. Table 4 summarizes the study parameters.

Table 4: Study Design Parameters			
Program Years	Intervention Years 2-4		
Unit of Analysis	Site		
Sample Size	30 sites (15 treatment, 15 control/delayed treatment) 6,085 students (3,042 treatment, 3,042 control)		
Primary Outcome Measures (see Appendix I for further details)	**Outcome**	**Instrument**	**Description**
	Literacy Outcomes		
	Literacy Skills Progress	Daily Benchmark Reading Assessment	Determines students independent and instructional reading achievement
	Early Language Skills	Phonological Awareness Literacy Screening (PALS)	Measures developing knowledge of literacy fundamentals
	Reading Skills	The Developmental Reading Assessment- 2 (DRA-2)	Formative reading level assessment
	Math Skills	STAR Math Assessment	Computer-adaptive math achievement assessment
	Technology Outcomes		
	Coding	Solve-Its	Assesses programming knowledge
	Computational Thinking (CT)	TACTIC	Classifies Computational Thinking abilities into seven domains and four proficiency levels

	CT- Related Problem Solving	Tech Check	“Unplugged” Computational Thinking abilities related to general problem-solving skills
	Technological Learning Environment	Positive Technological Development (PTD) Environment Check List / Educator Interviews and Surveys	Observational checklist to assess the classroom technological environment Semi structured student interviews Perception surveys, design journals
Co-variates /Baseline Equivalence	Student (pre-test scores, race/ethnicity, poverty level, gender, grade); teacher (teacher education and teaching experience measured by surveys), and school levels (publicly-reported school average achievement and demographics)		

D2. Evaluation: effective strategies for replication and testing in other settings

A **transfer and sustainability study** will explore the status of the CS curriculum implementation as there is transferring of implementation capacity to Tech leaders. The study will focus on Group 2. This study will address two research questions: 1) *How does implementation of CS curriculum change across Intervention Years 2 and 3 as DevTech transfers CS training and support to district leaders*? and 2) *How do district leaders and teachers perceive the sustainability of CS curriculum*? During Intervention Years 2-3, data on new teacher training and support will be collected. Interviews will be transcribed and analyzed using Dedoose to identify themes. Themes will be compared between Group 1 and 2 to explore changes after DevTech transfers its role in professional development to the Tech leaders team. In addition, the fidelity indices (see Evaluation Plan section D4) will provide information about the level of fidelity of implementation across the two groups.

D3. Evaluation: valid and reliable performance data on relevant outcomes

The evaluation will use a mixed-methods approach, combining multiple qualitative and quantitative data sources (Table 1) for data triangulation, thereby significantly enhancing the validity and reliability of the evaluation. Quantitative data sources include: Daily Benchmark Reading Assessment, PALS, DRA-2, STAR Solve-It assessments TACTIC, Tech Check. All instruments have been validated and field tested in a pilot study involving nearly N=600 students in Norfolk, Virginia (see Appendix I for more information). Quantitative data will be analyzed using descriptive statistics; parametric and non-parametric inferential statistics; and effect sizes disaggregated by subgroups. Qualitative data to assess the implementation fidelity of the project include: key informant interviews with site personnel, and partners; classroom observation, meeting minutes; and open-ended items on teacher surveys. Qualitative data analysis will be guided by code development (Saldaña, 2016) and informed by scholarly literature and stakeholder review panels (Frierson, et al., 2010). Responsible records management will be ensured by maintaining a roster of de-identifiable student data, secured throughout the years. Records of participants' progress, annual evaluations completed by teachers will be filed by program year. We will also maintain copies of the annual performance reports submitted to the Department of Education.

D4. Evaluation: key project components

Through a robust **implementation study**, the evaluation will document and track key project components, mediators that affect implementation, and outcomes as discussed above. The implementation study, which spans groups 1 and 2, will support replication and testing by pursuing three overarching questions:1*) To what extent was the CS curriculum implemented with fidelity at participating sites?, 2) How is the fidelity of the CS curriculum intervention affected by the selected training model (DevTech direct training, train-the-trainer model)?, and 3) How does the fidelity of implementation moderate the impact of the CS curriculum intervention on student outcomes?* We will launch a comprehensive longitudinal fidelity of implementation study to systematically track, document, and assess the extent to which actual project implementation aligns with proposed project implementation beginning in Implementation Year 1. Two fidelity indices -- fidelity of intervention and status of teacher implementation of intervention – will be developed by the RE team, in partnership with the leadership team in alignment with the logic model (Appendix G). Within each component, fidelity scores will be based on quantitative and qualitative indicators. Thresholds will be established a priori for each indicator using baseline data, scaling targets, and input from subject-area experts from DevTech. Beginning in Year 2, we will use findings from the prior implementation year to support replication in the Group 2 schools. Our evaluator will chart actual progress against our targets quarterly to support continuous improvement and iterative development, help interpret overall impacts, and explain any variation in impact across teachers and sites.

Data sources for the fidelity indices include teacher surveys, semi structured interviews, pre and post assessments before and after the training, as well as classrooms logs and google analytics to determine on-line resources usage; see Table 1 for a detailed listing of implementation data. Semi-structured interviews and surveys will be conducted annually with teachers. Surveys will measure perceptions of knowledge, quality of instruction, attitudes toward the CS curriculum, and perceived impacts of CS curriculum on student skills (including whether impacts are similar for students who are not proficient in English). Instructional logs will measure implementation status of select CS curriculum modules. In addition, administrative records of teacher participation in key project components, including teacher training seminars, tiered coaching, and online modules.

Data analysis methods vary by data source. Interviews will be transcribed and analyzed using Dedoose or other qualitative data analysis software to identify and compare themes. Data from surveys, logs, interviews, and document reviews will be used to generate two fidelity indices introduced above. Descriptively, the fidelity of intervention index will assess the coherency of training focus, duration, intensity, and alignment to CS curriculum of professional development activities. In addition, we will model associations between fidelity of intervention and status of implementation of CS curriculum within a multiple regression framework, controlling for teacher characteristics. We will also estimate 2-level HLM to examine how LEVEL 2 indicators of the status of CS curriculum implementation moderate treatment effects on LEVEL 1 student outcomes.