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ExCELL in Science for High-Need Pre-Kindergartens: The Early Phase

This Early Phase project addresses ***Absolute Priority 1*** (Demonstrates a Rationale/Evidence of Prior Effectiveness) and ***Absolute Priority 3*** (Field Initiated Innovations – Promoting Equity in Student Access in Educational Resources and Opportunities: STEM) by developing and evaluating a pre-kindergarten (PreK) science program that guides teachers serving children from historically underserved, high-need communities to build children's foundational science knowledge before formal schooling begins. Specifically, our *ExCELL in Science* program responds to the current lack of systematic early science instruction by providing teachers with science content grounded in the Next Generation Science Standards (NGSS) as well as effective, evidence-based, inquiry-promoting instructional strategies for teaching this content to young children. *ExCELL in Science* will provide PreK teachers with detailed science lesson plans for their classrooms; self-paced, online professional development (PD) modules to build their own knowledge about science content and inquiry-focused exchanges; individualized classroom coaching; and books and other materials to support the implementation of the lessons.

We also target ***Competitive Preference Priority 1*** (Promoting Equity in Student Access) by partnering with North Carolina Central University (NCCU), a minority serving institution (MSI) with a student population of 91% percent people of color, and by partnering with the School District of Philadelphia (SDP), a high-need district where PreKs have no structured science curriculum. We define high-need students as PreK children from low-income backgrounds and under-resourced communities, who have historically performed below national expectations (NCES, 2023). Finally, we address ***Competitive Preference Priority 2*** (Impact of COVID) by working with PreK teachers to map their current assets around early science and to assess outstanding needs, and by tailoring the *ExCELL in Science* program to respond to the post-

COVID needs of educators and children. Ultimately, *ExCELL in Science* will innovatively translate proven principles of science inquiry into feasible classroom practices for high-need PreKs, laying the foundation for stronger science engagement and performance for American students.

A. SIGNIFICANCE

Challenges of Existing Strategies and Practices: Inequity in Access to Science in PreK

This innovative *ExCELL in Science* model is grounded in multiple evidence-based premises.

Premise 1-Need for stronger science instruction: National data show that only one-third of 4th graders are proficient in essential science content (NCES, 2019), lagging other industrialized nations (IEA 2015). In recognition, the National Science Board (2020)'s Vision 2030 urged the nation to improve our global standing in STEM by focusing on *growing talent* and providing students with world-class, high-quality, evidence-based and equitable STEM education. But a primary challenge to this goal is that most early-grade classrooms offer limited instruction in science, especially through conceptually rich, inquiry-based learning, and particularly in high-need communities (NASEM, 2022). In fact, structural inequities in science education access are apparent as early as preschool (Curran & Kellogg, 2016; Nayfeld et al., 2013).

Premise 2-Early science yields later benefits: Exposure to science at a young age, especially through inquiry-focused experiences where children use language to discover and discuss science concepts, increases children's knowledge, interest and motivation in science over time (Curran & Kitchin, 2019; Grenell, et al., 2024; Morgan et al., 2016). Indeed, early science experiences are essential for long-term identity development as someone interested in science (Nasir & Cooks, 2009), a finding which has in part spurred recent, high-profile calls to the nation (NASEM, 2022) for strong, equitable early science experiences.

Premise 3-PreK offers little support for early science: Despite the promise of early science for later success, there are very few widely available PreK science programs (What Works Clearinghouse [WWC], 2023). Even as the availability of universal preschool has increased nationally (Friedman-Krauss et al., 2023), science remains under-emphasized in early learning experiences. For example, the NGSS begins in kindergarten, leaving PreK out, and only 11 states have science standards for PreK. Moreover, most widely used early childhood curricula (e.g., Creative Curriculum, High Scope) do not provide a discrete scope and sequence of science activities or study student science learning in impact studies (e.g., AIR, 2021; Creative Curriculum, 2013). As a result, early childhood teachers lack access to the evidence-based professional development and classroom activities that they need to effectively teach science.

Premise 4-Early science inquiry learning involves language exchanges, which can be challenging in PreK: Science learning does not emerge in isolation. Because it involves an inquiry process, driven by conversations replete with questions, responses, and meaningful feedback, teachers' support for children's language and vocabulary plays an essential role. Accordingly, effective science teaching is more than the teacher simply conducting an experiment in front of children. Instead, effective, inquiry-based science teaching relies in part on teachers' support of children's use of language to discuss and express their hypotheses, observations, and conclusions about science concepts. But while child talk and adult-child conversation are active ingredients in science learning (Justice et al., 2018), PreK classrooms often make conversation about content difficult. Teacher talk predominates, while extended child talk is relatively rare (Kane et al., 2023). Further, teacher talk is largely focused on giving directions and managing behavior (Sawyer et al., 2018). And, when teacher-child conversations do occur, they are typically structured as a closed-ended teacher question ("Did you finish the picture?) followed by a brief child response ("Yes"), with simple teacher feedback ("Good job"). However, effective professional development, such as our own ExCELL model (See p. 5), can transform these exchanges and help them build children's language ([redacted] & [redacted], 2020).

Taken together, the evidence shows the need for a high-quality early science program that targets NGSS science concepts while integrating effective language- and vocabulary-building techniques, so that teachers can equitably build science knowledge among all young children.

Promising New Strategies: *ExCELL in Science's* Innovative Approach to Science Equity

ExCELL in Science (EiS) represents a promising and innovative solution to the pressing need for equitable early science programming in PreK. We discuss our innovations below.

Innovation 1-Grounded in NGSS: To ensure that *EiS* addresses high-quality early science content, the lesson plans and classroom materials, PD, and coaching will be designed based on the leading science framework from the National Research Council (NRC, 2012; Nordine & Lee, 2021) and echoed in the NGSS (NGSS Lead States, 2013). Specifically, embracing *the three-dimensional approach*, *EiS* will teach children to think like scientists through emphasizing scientific practices such as asking questions, planning and carrying out investigations, and analyzing and interpreting data. These practices will be used to explore disciplinary core ideas within the four science domains: life science, physical science, earth/space science, and engineering, technology, and applied science. *EiS* will also elucidate crosscutting concepts across disciplines (e.g., patterns, cause & effect). As a result, *EiS* will, aligned with NGSS, establish a broad and deep foundation for three-dimensional science learning among PreK students.

Innovation 2-Cost effective and accessible: PreK teachers in high-need settings face two main challenges in obtaining and implementing science activities: finding needed classroom materials to engage children in science and accessing relevant professional development (PD) on how best to implement the activities. To this end, *EiS* will consider cost in multiple ways. First, *EiS* teacher PD will be online and self-paced, reducing financial and personnel costs related to travel, meeting space, and schedule conflicts, making it cost-effective and accessible. Second, *EiS* will intentionally design activities around materials commonly found in PreK classrooms, in part through an initial asset mapping/needs assessment phase that gathers teachers' input on gaps in their understanding and/or available tools for engaging children in science in the post-COVID era. Third, *EiS* will make extensive use of children's own environments (e.g., local weather patterns, force and motion with common toys, etc.) as the focal, NGSS-aligned content.

Innovation 3-Inquiry conversation strategies: *EiS* will explicitly help teachers support inquiry-focused exchanges among all children, including English monolingual (EMs) children and children learning English and another language (English Learners; ELs). Specifically, *EiS* will be aligned with our proven ([redacted] & [redacted], 2011; 2016; 2020) ExCELL (Exceptional Coaching for Early Language and Literacy) model for PreK settings. ExCELL is a year-long online PD with coaching that trains teachers to develop language and vocabulary skills in PreK students (both EMs and ELs). ExCELL has been shown, through a series of randomized controlled trials (see [redacted] & [redacted], 2020, in WWC) to significantly raise the quality of teachers' language interactions with children on the CLASS, a standardized instrument of instructional interaction quality (d=.75, a large effect), and also to build children's knowledge of vocabulary targeted in the curriculum (d=.60, a large effect) and, critically, even their standardized vocabulary (d=.12, a small effect). These results show that ExCELL is one of only five PD programs helping high-need learners catch up to their more advantaged peers in their language and vocabulary skills (Marulis & Neuman, 2010). Because learning science concepts requires learning new language and vocabulary through conversations, *EiS* will fold these language-related processes into the teaching of science to all children in the classroom.

Innovation 4-Cultural and Linguistic Responsiveness: Fourth, with the growing diversity among PreK students, *EiS* will also embrace key design principles of cultural and linguistic responsiveness. First, recognizing that children come to *EiS* with highly varied experiences in science and in the larger world, we will intentionally open *EiS* lesson plans by building background knowledge, clearly explaining new words and ideas. Second, lesson plans will foster conversations about children's personal experiences with science content, positioning children from all backgrounds to establish themselves as experts. Third, selected books and materials will represent a wide variety of characters, including a preponderance of children of color. Fourth, PD will train teachers to support the language development of ELs and EMs who speak dialects of English and to use culturally responsive practices (e.g., integrating the home language, building on children's funds of knowledge; Mathematica, 2019). Our partnership with North Carolina Central University adds expertise in supporting early science learning among ethnically and linguistically minoritized learners. Finally, integrating art, including drawing and movement, into science activities allows children to share and receive information in varied ways.

Innovation 5-Integrates with PreK thematic curricula: Finally, *EiS* will be highly scalable because it articulates with common theme-based PreK curricula. Most, if not all, PreK curricula are structured around themes (e.g., seasons, animals and habitats, trees) that require approximately one month to complete, with activities for all content areas integrated around the theme. Accordingly, *EiS* will be structured around 10 themes common to all widely-used PreK curricula, so that the science activities can be slotted into any thematic curriculum.

B. QUALITY OF THE PROJECT DESIGN

B.1 Conceptual Framework

EiS is founded on the idea that PreK children will learn science best when teachers are able to present rigorous, NGSS-aligned content using instructional strategies that effectively foster child inquiry through talk. As depicted in our Logic Model (Appendix G), we first posit that the PreK science content at the heart of the four components of *EiS* (lesson plans, books/materials, PD, and coaching) must be aligned with the NGSS's three-dimensional science learning. Specifically, *EiS* will support students' active engagement with essential practices in physical, life, earth & space science, and engineering design; broadly, these include defining problems, planning and carrying out investigations, analyzing data, and designing solutions. Each *EiS* lesson plan will also link its essential topic to deeper disciplinary core ideas in the domain of interest, as well as to related cross-cutting concepts that weave through domains. Second, we posit that teachers need to deliver this NGSS-aligned science content in ways that encourage children's participation in the inquiry process, including through language-building strategies that are integral to the practices (e.g., asking open-ended questions, defining science vocabulary, providing rich feedback, fostering extended conversations using science vocabulary). *EiS* is built on the proven ExCELL model (See p. 5) and will include ExCELL conversation-building content to ensure that teachers engage children in higher-order thinking and inquiry about science.

Third, *EiS* recognizes that teachers are learners of science (Bransford, et al., 2000), and that the COVID era complicated instruction in science (and other areas). To refresh and/or build familiarity with science content and inquiry strategies, teachers need ongoing professional development, including self-paced training modules that they can consult repeatedly over time and individualized coaching to help them use module strategies successfully in their own classrooms. *EiS* will be a year-long program that helps teachers build professional learning communities to sustain their science practices after PD ends. In turn, each of these PD inputs –

science content, inquiry strategies, and ongoing coaching – will lead to more teacher science knowledge, higher science-teaching self-efficacy, and high-fidelity implementation of *EiS* in PreK. Finally, teachers' high-fidelity *EiS* activities will lead to children's science learning and language development. Over time, children will be prepared for elementary-grade, NGSS-based science instruction, and teachers will use their increased science teaching skills to serve more PreK students. Thus, *EiS* will be sustained in the district, creating cycles of science success.

Description of the ExCELL in Science (*EiS*) Program

Building on the conceptual model underlying *EiS*, we plan four main components.

Component 1-Science Lesson Plans: Lesson plans, aligned with NGSS kindergarten PS2, PS3, LS1, ESS2, ESS3, and ETS1 Disciplinary Core Ideas (DCIs), will each fit within one of 10 common, month-long PreK themes relevant for culturally and linguistically diverse children. We will provide 4 weeks of lesson plans per theme, 3 lessons per week (i.e., 120 lesson plans total).

Each science lesson plan will follow a common structure, summarized below, beginning with a science objective and background information for the teacher, and then specific vocabulary and questions to share with children. (See Appendix J). Activities will draw on naturally occurring scientific events that are relevant for young children's lives (e.g., sinking & floating cups in water; push & pull with a heavy doorstop), reducing materials costs and increasing child interest.

Core Components of the Theme-based Lesson Plans
1. Science objective and performance expectations based on IDC and CCC
2. Teacher-friendly explanation of the science concept(s) under investigation, to assist teachers in refreshing themselves on relevant content knowledge
3. Step-by-step instructions for hands-on activities that can easily implemented, with any uncommon but essential materials (e.g., ping pong and tennis balls) provided
4. 4-5 vocabulary words aligned with science concepts on cards with photos and child-friendly definitions in English, Spanish and Mandarin (the most common languages in SDP)

5. 3-4 open-ended inquiry-fostering questions for use before, during, & after the activity, to develop children's science content knowledge & ability to use language to discuss concepts
6. Suggested PreK-level trade books for teachers to read aloud, reinforcing the science vocabulary and re-explaining the science concepts (about 2 books per theme provided)
7. A list of commonly available classroom materials needed for the lesson science activities

Component 2-Books and Materials: Fiction and nonfiction books offer children windows into the world beyond their own personal experience (Ganea et al., 2008, [redacted] et al., 2016). Therefore, each lesson plan will reference a trade book provided by *EiS* that is related to the science concept being taught and reflective of the cultural, racial, and linguistic diversity of our high-need communities. Additionally, we will list the commonly available classroom materials needed for activities, and on occasion will provide less common materials (e.g., rain gauge).

Component 3-Teacher Professional Development modules (PD): PD will include 6 online training modules, with anticipated topics listed below. Overall, the PD aims to build teachers' conceptual and procedural knowledge around early science ideas and instructional strategies so they can use the lesson plans and books/materials with confidence, fidelity and quality.

Topics of *EiS* Teacher PD Modules
Module #1: Get to Know the Science Lesson Plans: Why NGSS and science domains are important for PreK and how to learn what you need to know about the domains
Module # 2: What is three-dimensional learning? Tips for presenting science content (including Disciplinary Core Ideas & Cross-Cutting Concepts) to PreK Children
Module #3: How do we get children talking about science inquiry and concepts? Tips for encouraging Inquiry through Discussion (e.g., explaining science vocabulary words, asking open-ended questions, providing feedback to scaffold learning) for EMs and ELs
Module #4: How can playing with science facilitate inquiry-based learning and conversation? Tips for teaching science through play-based and art activities while encouraging child talk
Module #5: How can we emphasize science vocabulary? Tips for Introducing Science Vocabulary & Using it throughout the Day
Module #6: How can we adjust the science lesson plans to meet children's individual needs? Tips for small-group differentiation, including ELs and children with special needs

Similar to our ExCELL PD modules, each training module will begin with a brief, video-based explanation of the importance of the module's content for early science learning. Next, teachers will read about 3-5 strategies and, for each, watch brief video exemplars of a PreK teacher demonstrating the strategy in a classroom serving diverse, high-need learners. Check Your Understanding quizzes (with immediate feedback) will follow each strategy to ensure teachers' understanding. Each self-paced module will take about 60 minutes to complete. Teachers will complete one module per month.

Component 4-Individualized Coaching: Each module will end with an assignment for teachers to practice what they learned about in their classroom and, after 1 week, an expert coach will visit the classroom to observe. The coach will video-record the teacher for 30-45 mins as they teach an *EiS* science lesson using the strategies from the module. During the observation, the coach will complete a project-aligned fidelity measure to gauge the teacher's use of the module strategies. After the observation, the coach will write a short commentary on at least one glow (strength) and grow (area to improve) and identify clips from the video reflective of each. The coach will share the write-up and clips with the teacher in advance of a 30-45 min coaching session. The coach will observe/conference twice per month with each teacher.

B. 2. Goals and Objectives

Goals and objectives for developing *EiS* are structured around an iterative process, beginning with a needs assessment/asset mapping of resources/needs after COVID, and proceeding through multiple rounds of careful observation and revision, helping to ensure the relevance and feasibility of *EiS* in high-need PreK classrooms. Thereafter, a fully powered RCT offers a rigorous determination of the program's effectiveness. Finally, we focus on making *EiS* sustainable in the SDP and beyond, resulting in widespread innovation for early science learning.

Table 1. Project Goals, Objectives, and Outcomes

Goal 1: Gather information about local context to inform *EiS'* development/implementation.
***Obj. 1A*.** Conduct asset mapping and needs assessment by interviewing and surveying 10 PreK teachers and administrators from SDP about their assets, needs and challenges related to early science instruction and to understand the impact COVID has had on PreK. This information will inform the development of *EiS* to ensure that post-COVID needs are met. ***Outcome**:* Completed early science asset & needs map to inform the development of *EiS*.
***Obj 1B*.** Create an advisory board (AB) that meets 3 times/year throughout the project. The board will consist of 2 principals, 4 teachers and 2 parents from early childhood programs in SDP. Throughout the project, the AB will provide input on *EiS* and the effects of COVID, review the science materials including lesson plans and PD, and help implement and sustain the project in SDP schools. ***Outcome**:* AB created that supports the development of *EiS*.
Goal 2: To iteratively develop *EiS* to support PreK classrooms in high-needs communities.
Obj. 2A. Develop theme-based science lesson plans structured around three-dimensional science learning. We will develop 12 lessons for each of the 10 themes through an iterative process, whereby the lesson plans are created; feedback is obtained from 6 teachers and the AB; and the lesson plans are revised. ***Outcome**:* Complete set of *EiS* lesson plans created that will be tested in pilot and feasibility studies.
Obj 2B. Develop PD training modules through an iterative process. The modules will be reviewed by 6 teachers and the AB and revised accordingly. ***Outcome**:* Complete set of *EiS* PD modules created to be tested in the pilot and feasibility studies.
***Obj. 2C*.** Develop a first draft of an *EiS* fidelity measure and teacher science content knowledge measure. After drafting these, feedback will be obtained from 6 teachers and the AB, and both measures will be revised. ***Outcome**:* Ready-to-use content and fidelity measures to try out in the pilot and feasibility studies.
Goal 3: Conduct a pilot study of *EiS* & train 6 teachers to ensure *EiS* effectiveness & fidelity.
***Obj. 3A*.** Recruit and train 6 teachers in *EiS* using the modules and coaching. Teachers will implement *EiS*, complete the modules, and receive coaching, over a 6-month period. ***Outcome**:* All 6 teachers trained and progress toward fidelity in *EiS*. 108 children served.
Obj 3B*.** Examine the impact of *EiS* on educators and identify any potential barriers to successful implementation. During the pilot, we will collect data pre-and post-implementation and through the pilot, as outlined in the outcome. ***Outcome: Monthly updates from the master coach on teachers' participation in PD and implementation of *EiS* in classrooms (e.g., completion of modules, checks of teacher comprehension built into modules, and fidelity of implementation), performance on pre-/post- performance on science content knowledge measure, and teacher ratings of and interviews about the effectiveness of *EiS*.
Obj. 3C: Use information from *Obj 3B* to make revisions to lesson plans, science knowledge measure, and fidelity instrument. Data will be analyzed, results compiled and shared with the

AB for feedback. Revisions will then be made accordingly. ***Outcome:*** A revised version *EiS,* science measure and fidelity instrument to be used in the feasibility study in Goal 4.
Goal 4. Conduct a feasibility study by training 10 teachers with the revised version of *EiS* to ensure the feasibility of the program, and collecting teacher and child outcome data.
Obj. 4A: Recruit and train 10 teachers in *EiS* using the modules and coaching. Teachers will implement *EiS* in their classrooms, completing the PD and receiving coaching over the full school year. Ensure that post-pilot revisions are effective and that *EiS* is feasible. ***Outcome:*** All 10 teachers trained to fidelity in *EiS*. At least 180 receive *EiS.*
Obj 4B*.** Examine the impact of *EiS* on educators and children, and identify any potential barriers to successful implementation. As with the pilot, data will be collected pre- and post-implementation and throughout the implementation period. ***Outcome: Monthly updates from the master coach on teachers' implementation, including fidelity (See *Obj 3B)*, teacher ratings and year-end interviews on the effectiveness of *EiS*, as well as data on participant change over the full academic year of *EiS* (e.g., Pre-/post- science knowledge measure, and observation of teacher instruction and fidelity; pre-/post-test child science knowledge and vocabulary).
Obj. 4C: Use information from *Obj 4B* to make final revisions to *EiS*. Data will be analyzed, results compiled and shared with the advisory board for feedback. Revisions will be made. ***Outcome:*** Fully revised versions of all *EiS* components ready for the independent evaluation.
Goal 5: Train teachers in *EiS*, reduce science inequities and address needs that result from COVID, and conduct an independent evaluation.
Obj. 5A: Recruit 80 teachers and 10 children in each classroom; randomize classrooms to condition. In brief, 80 PreK teachers will be recruited and randomized into the intervention (Cohort 1 receiving *EiS* in 2026-27) or waitlist control (Cohort 2 receiving *EiS* in 2027-28). ***Outcome:*** Teachers and children recruited. Prepared to conduct fully powered RCT of *EiS*.
Obj. 5B: Train 80 teachers and at least 1440 children (18 children per classroom trained, 10 of the 18 children per classroom in the study) in *EiS* over two school years. Teachers will be pre- and post-tested on their content knowledge, fidelity and quality of instruction (science and interaction quality). Children will be pre- and post-tested on science content knowledge, project-aligned vocabulary, and standardized vocabulary. ***Outcome:*** 80 teachers trained and able to implement *EiS* with fidelity; at least 1440 PreK children receive *EiS*.
Obj. 5C: Collect and analyze data pre- and post-intervention and prepare a report. See the Evaluation for sources of data. Our independent evaluator will collect and analyze the data. We will conduct a cost analysis to determine cost per student. ***Outcome:*** Pre- and post-data analyzed, and final report created. Cost analysis will be included in the final report.
Goal 6: Sustain *EiS* in SDP & broadly disseminate results to implement *EiS* in other districts.
Obj. 6A: Create sustainability of *EiS* in the SDP. Communicate regularly with SDP through AB, emails and Zoom calls with district administrators, and hold a minimum of 3 formal meetings with administrators, all years. ***Outcome:*** Ongoing use of *EiS* throughout SDP PreK.

Obj. 6B: Broadly disseminate results. ***Outcome:*** Presenting on *EiS* at a 3 research-oriented and 3 practitioner-oriented conferences and authoring a min. of 2 research-oriented and 2 practitioner-oriented manuscripts.

B.3 Extent to Which the Design Meets the Needs of the Target Population

Target population. *Ei*S intends to provide equitable, accessible science instruction for high-need PreK students. To achieve this, we will recruit PreK classrooms in Philadelphia, the poorest big city in the nation, - including an astounding 32% of young children. Overall, approx. 80% of SDP children, and 95% of PreK children, are eligible for free/reduced-price lunch, far exceeding the NCES (2023) threshold for high-need status. Students are ethnically and linguistically diverse: children are predominately (75%) of Black and/or Latine ethnicities, and 20% are ELs (half speaking Spanish, but more than 20 languages are spoken in total). Matching historic national trends of underservice for these groups, in 2023, only 11% of Hispanic and 9.3% of Black 4^{th} graders in SDP reached grade proficiency on the state science test.

Meeting their needs. Our project is designed to successfully meet the needs and nurture the knowledge of high-need students, including racial and linguistic minority children who have historically been left behind. First, *EiS* will be rooted in world-class, NGSS three-dimensional science principles to foster robust science learning. The NGSS paradigm is an essential foundation, because it provides an evidence-based body of science knowledge that children need to learn about, with an emphasis on both broad (cross-cutting concepts) and deep (core ideas) learning to help students understand and remember over time. Second, our development process begins by conducting an asset map and needs assessment with teachers and principals from SDP, which will help us tailor *EiS* to the needs that have arisen since COVID. Third, building on this foundation, *EiS* will be developed over time, in close collaboration with the end users, via the feedback-intensive pilot and feasibility studies and the Advisory Board contributions. Fourth, with support from our NCCU partners, lesson plans will harness culturally and linguistically responsive strategies that help teachers access the unique knowledge and expertise of their diverse students. Fifth, *EiS* will include our proven ExCELL language and vocabulary strategies to support early language proficiency, which is the best predictor of success in school. Finally, to ensure that teachers implement the rich, inquiry-focused science lessons with fidelity, *EiS* will provide evidence-based training and coaching over a full school year, building teachers' own science content knowledge and their science pedagogical knowledge. Taken together, *EiS* is well-positioned to support high-need learners in SDP and, ultimately, at scale across the US.

C. QUALITY OF PROJECT PERSONNEL

Commitment to Hire Members of Under-Represented Groups

The Leadership Team, which consists of [redacted], [redacted] and [redacted], will actively recruit and work with under-represented and diverse populations under this grant. In their most recent grant together, 50% of the coaches and project coordinators were from under-represented populations. At Teachers College (TC), nearly 30% of the student body comes from an under-represented group based on race and ethnicity. In addition, 39% of School District of Philadelphia teachers are from under-represented racial/ethnic groups and 74% are female. The Project Coordinator to be hired will be a Spanish-English bilingual and a native speaker of Spanish, which means they will likely be Hispanic. Also, we will seek coaches and data collectors who are from diverse backgrounds and who are bilingual.

Project Personnel: Our team represents a dynamic partnership among individuals with expertise in science education, early childhood education, language and literacy, English learners, culturally and linguistic diversity, and special education from 4 universities: Teachers College-Columbia University, Temple University, University of North Carolina-Chapel Hill, and

North Carolina Central University, an HBCU and MSI. The Leadership Team ([redacted], [redacted], & [redacted]) who have worked together for 15 years, have extensive experience providing PD to early childhood teachers in high needs districts and supporting the development of children from diverse cultural and linguistic backgrounds. In addition, they have co-led 10 design and development projects funded by federal agencies including the US Department of Education.

[redacted]*, Ph.D.,* is PI and Professor of Communication Sciences and Disorders at Teachers College, Columbia University. She is co-developer of *ExCELL* and a national expert on ELs' language and literacy development, cultural and linguistic diversity, teacher PD and special education. [redacted] will oversee all aspects of the project, including ensuring that content is culturally and linguistically responsive and meets the needs of English learners. She has led or co-led 11 federally funded grants ($30 million total), and has 90 articles.

[redacted]*, Ph.D.*, Co-Principal Investigator (Co-PI), is a Professor and the PNC Endowed Chair of Early Childhood Education at Temple University. [redacted] will partner with and co-lead the project with [redacted] and [redacted] and will lead the creation of *EiS*. She is a national expert in science education and in early language and literacy PD interventions, with 30 years of experience in public preschools. She is the original developer of ExCELL and the lead developer of the PNC Grow Up Great Science Lesson Center. She also has published articles on how early science offers a vehicle for building language skills, critical thinking, and reading skills. [redacted] has implemented several large-scale preschool interventions in high-needs school districts such as Philadelphia, New York City and Baltimore. She has received over 10 Department of Education grants, including the IES, i3, and Early Reading First funding streams.

[redacted]*, Ph.D.,* is Co-PI and Professor of Special/Inclusive Education in the School of Education at University of North Carolina-Chapel Hill and a co-developer of ExCELL.

She will co-lead the project, focusing on managing the iterative process of teacher and AB feedback collection and revision in Years 1-3. She will also act as a liaison with the evaluation team and will also oversee the cost analysis. She began her career as a Head Start educator in New Haven, CT, and then became a literacy coach in Baltimore, MD and Detroit, MI. She has been PI or Co-PI on more than $20M in grant funding from federal and private sources and has authored more than 80 publications.

[redacted], *Ph.D.,* is an Associate Professor in the Department of Biological & Biomedical Sciences and Director of the Center for Science, Math, and Technology Education at North Carolina Central University, and HBCU and MSI. She has over twenty years of teaching and research experience that supports project-based learning for early/elementary children, undergraduate research activities, and co-curricular and entrepreneurial thinking. She has published several journal articles on course-based research experiences and retention of STEM majors at HBCUs. Her role in *EiS* will involve supporting the development of classroom activities and science content PD for teachers, including building confidence around science.

[redacted], *Ph.D.*, Professor of Education, Utah State University, will partner with the team as they develop *EiS*. [redacted] is a nationally recognized expert in science education in early childhood. She has over 200 publications and was awarded over $26 million in federal funding in science education. In 2023, she was awarded the Outstanding Longtime Service Award from the Association for Science Teacher Education. She will work with the team on ensuring that *EiS* is reflective of NGSS while being feasible in classrooms with young children.

[redacted], *M.E.*, Early Childhood Education Specialist, Smithsonian Air and Space Museum will also partner with the team and they develop *EiS*. At the museum, [redacted] develops learning experiences for young children and their families and also leads professional development in inquiry science for early childhood teachers. [redacted] will work with the team to ensure the *EiS* is reflective of NGSS and will be feasible in early childhood classrooms.

Independent Evaluator: [redacted], PhD, will lead the independent evaluation of *EiS*. She is a Principal Researcher at AIR where she leads studies of teacher PD and early childhood curricula. [redacted] began as a teacher and, over 20 years in education research, has led 12 research studies as principal investigator. Her expertise includes large-scale outreach and recruitment, as well as multipronged data collection (e.g., classroom observations, one-on-one student assessments, surveys, interviews). [redacted] is also a WWC-certified reviewer (v. 5.0).

Master Coach and Coach (To be Hired). The master coach and coach will have a master's degree in science education and/or early childhood education, experience teaching science, knowledge of culturally and linguistically responsive practices, and strong communication skills (bilingual preferred). The master coach and coach will have at least 5 years and 3 years of experience coaching, respectively. The master coach will assist with the development of *EiS* and will coach teachers during the pilot and feasibility studies. The master coach and coach will coach teachers during the independent evaluation.

Project Coordinator (To be Hired). The Project Coordinator will be bilingual and have a master's in science education and/or early childhood education with experience in research, classroom teaching and PD. The project coordinator will work closely with the team, manage the day-to-day operations, and support activities related to the development and implementation of *EiS.*

D. QUALITY OF THE MANAGEMENT PLAN

The PI ([redacted]) and CoPIs ([redacted] & [redacted]) will serve as the *Leadership Team (LT)*, who will oversee all aspects of the project, including the asset map/needs assessment, pilot and feasibility studies and training of teachers, collaboration with the SDP, and project personnel management (e.g., project coordinator, coaches). The LT also will lead the broader *EiS Partners*

(EP) group, who include the LT, [redacted] from NCCU, and our early childhood science consultants from USU and the Smithsonian. The EP will drive the iterative development process of the *EiS* lesson plans, PD, and coaching, consulting with the local Advisory Board (AB) throughout the project. The *Independent Evaluation (IE)* will be led by [redacted].

We have developed a comprehensive, 5-year **management plan** with goals, objectives, and milestones, specifying the individual(s) responsible (See Table 2). Essential tasks include: 1) conduct asset mapping/needs assessment (that addresses the effects of COVID); 2) develop *EiS* lesson plans, PD modules, fidelity measure and teacher science knowledge survey, and undertake several rounds of feedback and revision; 3) pilot *EiS* by training 6 teachers and revise using data and feedback; 4) explore feasibility by training 10 teachers and revise using data and feedback; 5) conduct a fully powered randomized controlled trial of *EiS* over two years [run by AIR, independent evaluator (IE)]; and 6) sustain the PD in the district and disseminate information about *EiS* through conference presentations and preparation of manuscripts for publication.

Continuous Improvement Plan: Across all years, the LT will implement a Continuous Improvement Plan. Specifically, the LT will meet (virtually) weekly with project staff to ensure timely progress on goals and objectives and minimization of threats to the project's success (e.g., delays in reaching milestones). They will communicate regularly with the SDP (e.g., emails, meetings) to maintain the collaborative partnership, ensuring progress and sustainability. The LT will also evaluate progress toward all goals/objectives monthly; elicit input from the program staff, AB and IE; identify any potential impediments to progress and make changes accordingly; and evaluate the utility of those changes. Finally, the LT will prepare and submit all quarterly and annual reports (IE to prepare evaluation report) to EIR and share these with our partners.

Table 2. Management Plan: Project Goals, Objectives, Responsible Personnel and Timeline

Key Terms: AB=Advisory Board, MC = Master Coach, C= Coach, EP=*EiS* Partners (Leadership Team, NCCU Partner & Science Consultants), IE = Independent Evaluator, LT= Leadership Team ([redacted], [redacted] & [redacted]), PC = Project Coordinator, **Dates:** YQ = Year & Quarter, ON- Ongoing		
Goals and Objectives	Personnel	Dates
Implement LT (weekly) and EP meetings (monthly)	LT, EP	ON
Communicate w/ & meet regularly with SDP, at least 3 formal meetings per year (min. of 1 on teacher recruitment)	LT	ON
Finalize partner roles & responsibilities, management plan	LT, EP	Y1Q1
Hire Project Coordinator and Master Coach	LT	Y1Q1
G1Obj. 1A. Conduct early science asset mapping & needs assessment to inform the development of *EiS*	EP, PC	Y1Q1
G1Obj 1B. Create Advisory Board (AB), meets 3 times/year	LT, PC	Y1Q1 & ON
G2Obj. 2A, 2B & 2C. Develop a basic set of *EiS* lessons, PD training modules, fidelity measure and science content knowledge measure – receive feedback and revise	EP, MC, AB	Y1Q2-Q4
G3Obj. 3A. Conduct pilot study – Train 6 teachers in *EiS*	LT	Y2Q1-Q2
G3Obj 3B. Examine the impact of *EIS* on educators and identify potential barriers to successful implementation	EP, PC, MC	Y2Q1-Q2
G3Obj. 3C: Use information from *Obj 3B* to make revisions to *EiS,* science knowledge measure, and fidelity instrument	EP, PC, MC, AB	Y2Q2
G4Obj. 4A: Conduct feasibility study-Train 10 teachers in *EIS*	LT	Y2Q3-Y3Q2
G4Obj 4B.; Collect pre- and post-test data on teachers to identify potential barriers	EP, PC, MC	Y2Q3 & Y3Q2
G4Obj. 4C: Use information from *Obj 4B* to revise to *EiS*	EP, AB	Y3Q2
Hire *EiS* coach	LT	Y3Q2
G5Obj. 5A: Recruit teachers for Independent Evaluation and randomize classrooms to condition. Recruit 10 children per classroom for Cohort 1 (Y 3) and Cohort 2 (Y4)	IE	Y3Q2-Q3
G5Obj.5B: Train 80 teachers and at least 1440 children in *EiS* over two school years.	MC, C	C1 Y3Q4-Y4Q3; C2 Y4Q4-Y5Q3

G5Obj. 5C: Collect and analyze data pre- and post-intervention and prepare a report, including cost analysis See Appendix J for a detailed timeline for the evaluation.	IE	Y3Q4-Y5Q4
G6Obj. 6A: Create sustainability of *EiS* in the SDP via 3 meetings with administrators per year, going forward	LT, PC, MC	ON
G6Obj. 6B: Broadly disseminate results	LT	ON

E. QUALITY OF THE PROJECT EVALUATION

E1. Methods to Generate Evidence That Meets WWC Standards Without Reservations

The American Institutes for Research (AIR), an independent research institution, will conduct an objective evaluation of *EiS* answering four research questions (RQs) about the program's impact. RQs 1 and 2 are confirmatory, whereas RQs 3 and 4 are exploratory. (RQ1) What is the impact of *EiS* on students' learning of science knowledge and vocabulary, compared to business-as-usual? (RQ2) What is the impact of *EiS* on teachers' knowledge, self-efficacy, and instructional practices? (RQ3) To what extent do student and teacher characteristics moderate the impact of *EiS* on student outcomes? (RQ4) To what extent do educators' instructional practices mediate the association between *EiS* and student learning? Finally, to inform continuous improvement of *EiS* and provide context for the impact findings, the evaluation also will address two RQs about the implementation of *EiS*: (RQ 5) To what extent do professional learning and instructional resources differ between the treatment and control groups? (RQ 6) What are the facilitators for and barriers to implementation of *EiS*?

Evaluation Design. AIR will conduct a blocked cluster randomized controlled trial (RCT), with random assignment at the educator level within blocks defined by site type (SDP public school or SDP community-based childcare center) and socioeconomic status (median household income in site's ZIP code), which will meet What Works Clearinghouse (WWC) evidence standards without reservations (WWC, 2022). In fall 2027 (see Obj. 5A), AIR will randomly assign teachers to treatment with *EiS* (Cohort 1) or a business-as-usual control group (Cohort 2), affording causal conclusions about the effects of *EiS*. Cohort 1 will receive *EiS* in the first year of the evaluation, and Cohort 2 will receive *EiS* in the second year. A likely minimal (as in Garet et al., 2016) risk to the internal validity of this design is that teachers in the same building could be randomized to different conditions, and control (Cohort 2) teachers could inadvertently receive some access to the treatment. To mitigate this risk, the team will (1) strictly control teachers' access to the online PD modules. Further, we will (2) instruct treatment (Cohort 1) teachers not to disclose any knowledge about *EiS* to control (Cohort 2), and we will track potential information-sharing via items in our end-of-year teacher survey. Finally, (3) control (Cohort 2) teachers will receive *EiS* in the second evaluation year.

We will recruit a total of 80 teachers and their students from the School District of Philadelphia's (SDP) PreK program, randomizing half to Cohort 1 and half to Cohort 2. Assuming that an average of 10 students per teacher consent to participate, the final study sample will include 800 students from 80 classrooms. Our power analysis (Appendix J) finds a minimum detectable effect size of 0.215 for student outcomes in RQ 1 and 0.391 for teacher outcomes in RQ 2, after accounting for 20% student and teacher attrition; these MDES are well-aligned with prior research. To minimize attrition, we provide teachers with books and $600 for participating in the project, and the control group (Cohort 2) will receive *EiS* and incentives only if they remain in the study till the second year. See Appendix J for detailed timeline.

Key Student and Teacher Outcomes. AIR field staff will assess the PreK teacher and 10 consenting students per class in both conditions at the beginning (fall, C1:Y3Q4 and C2:Y3Q4) and end (spring C1:Y4Q3, C2:Y5Q3) of the first year of the RCT, and then repeat the process with Cohort 2 classrooms in the second year. All measures meet WWC standards (i.e., valid, reliable, parallel across conditions, not over-aligned with *EiS*). (See Appendix J.)

Children's science content knowledge: (1) The Lens on Science (Lens) tool is a Rasch-derived, computer adaptive, direct, individual assessment of *NGSS-aligned science knowledge and skills* (Greenfield, 2015) tapping, in 10 mins, science practice skills and content knowledge. Reliability is 0.87. (2) The NCES measure created for the ECLS-K (2011) taps *general natural and science knowledge* via 20 items in 10 mins (DoE, n.d.; Rock & Pollack, 2002).

Children's vocabulary knowledge: (1) A direct, individual project-based vocabulary measure will be created by randomly selecting 15 *science-related vocabulary words from lesson plans* and using a novel image of each on a separate card, asking each child "What is this?" Children receive 2 points for a correct expressive answer and 0 for an incorrect answer ([redacted], [redacted], & [redacted], 2008). For any words children cannot identify expressively, the assessor will offer a receptive plate with an image of the word and three foils, asking "Show me [word]," giving 1 point for a correct receptive response. (2) The Peabody Picture Vocabulary Test, 5th edition (PPVT-5; Dunn, 2019) will measure *standardized vocabulary knowledge*. The PPVT-5 is a 10- to 15-minute norm-referenced, individual measure of receptive vocabulary (reliability=0.97) (Dunn, 2019).

Teachers' science knowledge: The Teacher Science Knowledge tool tapping *science content embedded in the PD modules* will be developed. Teachers will complete the measure online, before PD module 1 and after PD module 6. We anticipate a 15-min, multiple-choice tool.

Teachers' self-efficacy: The Science Teaching Self-Efficacy scale (Chen et al., 2022) is a 5-item survey gauging teachers' self-rated (on a 5-pt Likert scale from strongly agree to strongly disagree) *beliefs about their own science knowledge, lesson design, teaching, and concept explanation skills*. Cronbach's alpha is 0.85 (Chen et al., 2022).

Teachers' instructional practices: The (1) Science Teaching and Environment Rating Scale (STERS; Chalufour et al., 2003) is a classroom observation and teacher interview that rates the *quality of the science learning environment and teacher-student interactions during a science lesson*. A trained observer, blind to condition, watches a videotaped science lesson and rates teachers on several items (from 1=deficient to 4=exemplary). Cronbach's alpha is 0.96.

The (2) Classroom Assessment Scoring System-PreK (CLASS; Pianta et al., 2008) taps into *quality of the interaction* during the science lesson. A trained observer, blind to condition, watches the videotaped science lesson and scores the teacher (from 1=very low to 7=very high) on three facets of Instructional Support: concept development, language modeling, and quality of feedback. CLASS has high inter-rater reliability (above .85), internal reliability (above .85), and strong predictive validity for teacher practices (Hamre et al., 2012; Pakarinen et al., 2008).

Finally, the (3) *Project-Aligned Teacher Fidelity Measure* will be developed during the project for use by the coaches at each visit. A trained observer, blind to condition, will score the fall and spring science lesson video using the measure to tap specific strategies from the PD.

Impact Analysis. To address RQs 1 and 2, AIR will use stringent intent-to-treat (ITT) analyses, including all teachers in the groups to which they were randomly assigned (ignoring noncompliance and withdrawal), while also accounting for block fixed-effects. Confirmatory analyses for RQ1 will examine the impact of *EiS* on four student outcomes (i.e., Lens, ECLS-K science, PPVT-5, project-based science vocabulary), with separate models for each. Analyses for RQ2 will estimate the impact of *EiS* on teachers' content knowledge, self-efficacy, and three facets of instructional practice (STERS, CLASS, and the project-based fidelity tool). Impact estimates will be derived from hierarchical linear models (Raudenbush & Bryk, 2002; Appendix J). We will minimize the risk of late joiners by assessing only students whose parents consented prior to randomization. We will also control for various student and educator characteristics (e.g., teacher education, child EL status), improving precision of impact estimates.

An exploratory analysis (RQ3) will examine variations in treatment effects with student and teacher background characteristics, via incorporating interaction terms between treatment indicator and moderating variables into the primary impact model. For RQ4, AIR will examine instructional practices as a potential mediator between *EiS* and student outcomes using a structural equation model; we will separately test STERS, CLASS, and fidelity as mediators.

E2. Methods That Provide Performance Feedback and Periodic Assessment of Progress

Throughout the iterative development process (e.g., asset mapping, pilot and fidelity studies), the LT (Leadership Team) will share feedback and revisions with the AIR team to inform the upcoming evaluation. AIR will also interview pilot and fidelity teachers at the end of their participation to understand strengths and weaknesses of *EiS*. For RQ5, in the treatment group, the evaluation team will obtain data on teachers' completion of the PD modules and their Check Your Understanding scores (from the training portal); hours of coaching provided to each teacher; and observer ratings on the classroom fidelity tool. AIR will analyze and triangulate these data to assess teachers' engagement with and implementation of *EiS* and to identify patterns of content uptake and program implementation among participating teachers. We anticipate that, to reach fidelity, teachers must complete all online modules, participate in 90% of coaching cycles (observation and feedback), and use 85% of the instructional strategies on the project-aligned fidelity tool at each coaching observation. The AIR team will then use data collected to describe teachers' level of implementation for each indicator. The analysis will provide evidence of: (1) the extent to which professional learning activities are implemented with each teacher, and (2) variations in classroom implementation across teachers.

For RQ6, AIR will survey treatment and control teachers on their satisfaction with *EiS* and other professional learning experiences, as well as perceived barriers to (e.g., student behavioral issues, competing schedule demands) and facilitators of (e.g., student interest in science, materials availability) *EiS* implementation at the student, classroom, and school levels. AIR will also interview 12 Cohort 1 teachers at the end of the first year of the evaluation and 12 Cohort 2 teachers at the end of the second year to further explore barriers and facilitators. Transcript analysis in NVivo will identify emergent themes about teachers' experiences; AIR will share this feedback with the LT as formative data to support final improvements to *EiS*.

E3. Clear Articulation of Components, Mediators, Outcomes, and Thresholds

The RQs of the proposed evaluation follow the key components, mediators, and outcomes in the *EiS* intervention logic model (Appendix G). Teachers will use classroom lesson plans and books/materials, complete online PD modules, and receive coaching, which will raise their science content knowledge, science teaching self-efficacy, and use of effective science teaching strategies. In turn, students in this high-need setting will gain science content and vocabulary knowledge (project-based and generalized). As teachers' practices may be the key ingredient in child learning, we will test whether teachers' practices mediate effects on student outcomes. Finally, we explore the moderating role of various teacher and child background characteristics on the impact of *EiS*.

Fidelity of Implementation. To determine the extent to which *EiS* is implemented with fidelity, AIR will work with the implementation team to identify quantifiable indicators for the key activities in the logic model (e.g., teacher participation in PD modules) and determine thresholds for acceptable implementation (see anticipated thresholds above).