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A. Significance

In this Early-Phase research project, we propose to address **Absolute Priority 1** – *Demonstrates a Rationale* and **Absolute Priority 3**–*Field Initiated Innovations – Promoting Equity in Student Access to Educational Resources and Opportunities: STEM* by developing and implementing an innovative, integrated program to improve student mathematics achievement while developing student behaviors that support success and accessing academic content. Our program, **Math Ready-Supporting Early Number Sense (M-SENS)**, will be designed for kindergarten classrooms serving a high percentage of high-need students and will promote educational equity and adequacy in resources and opportunity for underserved students. This project will also attend to the Early-Phase competition's recognition of **Competitive Preference Priority 2**–*Addressing the Impact of COVID-19 on Students, Educators, and Faculty* by developing and implementing an integrated mathematics and behavior support program to ensure all students, particularly those students most affected by the educational disruptions caused by COVID-19, have the opportunity to successfully access high quality, evidence-based early mathematics instruction. M-SENS will be designed to result in three key outcomes: (a) accelerated student mathematics achievement, (b) reduced challenging student behaviors in whole-class settings, and (c) increased capacity of teachers to support student early mathematics and behavioral needs. At the conclusion of this proposed Early-Phase project, we anticipate generating sufficient evidence of promise of M-SENS to justify a subsequent Mid-Phase grant.

The low level of mathematics performance of U.S. students in relation to national standards and in international comparisons has concerned educators and policy makers for many years (National Research Council, 2001). Decades of data compiled from the National Assessment of Educational Progress (NAEP) highlight this stark reality and indicate that most students in the

U.S. are not meeting proficiency in mathematics (National Center for Education Statistics, 2019). While NAEP data indicate troubling levels of achievement at 4th grade, the longitudinal nature of mathematics development points to the critical importance of supporting early mathematics knowledge. Consistent findings across nationally-representative datasets reveal strong, stable relationships between early and later mathematics achievement (e.g. Bodovski et al., 2007; Duncan et al., 2007; Hanich et al., 2001; Morgan et al., 2009) and indicate that poor performance at school entry is strongly related to poor performance in later grades (Morgan et al., 2009). Early mathematics difficulties and mathematics achievement gaps are persistent (Geary, 1993; Morgan et al., 2009; Schoenfeld et al., 2012) and unless the needs of at-risk students are addressed early, they are likely to continue and become more difficult to remediate as students struggle to develop a solid foundation upon which to build an increasingly complex understanding of mathematics (Jordan et al., 2002; Morgan et al., 2009). Disruptions in learning caused by the COVID-19 pandemic have only further exacerbated these opportunity gaps for groups that have traditionally been vulnerable, including English learners, those with a disability, students living in poverty, and students of color from groups that have been historically underserved.

Critically, however, there is emerging evidence that even though trajectories are relatively stable, long-term trajectories can be altered during this period through the use of evidence-based practices (Morgan et al., 2014). Kindergarten is believed to be an optimal period in which to prevent and alter these early achievement gaps through evidence-based practices and ensure that all students are on-track for developing mathematical proficiency with whole numbers (Frye et al., 2013). Our work to date (e.g. [redacted] et al., 2016a, 2020; [redacted] et al., 2019b) and the work proposed in this project are part of a growing and robust research base (e.g. Fuchs et al., 2005;

Sood & Jittendra, 2013; Dyson et al., 2011) designed specifically to tackle this challenge.

Recognizing that mathematics trajectories are established early in school and that kindergarten represents a critical window of opportunity to support students' development of whole number understanding, we developed and tested ROOTS, a kindergarten mathematics intervention program, through Institute of Education Sciences (IES) funding (Grant numbers R305A080699 and R324A120304). ROOTS consists of 50 lessons and focuses on three key areas of whole number understanding: (a) Counting and Cardinality, (b) Operations and Algebraic Thinking, and (c) Number and Operations in Base 10 (see sample lessons in Appendix J). Students advance from objectives centered on counting objects and identifying numerals to applying their knowledge of foundational principles to number operations and the base 10 system. The Common Core State Standards for Mathematics (CCSS-M, 2010) recommends a deep and extensive coverage of whole number concepts and skills during kindergarten for all students. For kindergarten students at risk for mathematics difficulties, the focus on whole number is of even greater importance. A converging body of research suggests that an in-depth understanding of the whole number system is a critical step in achieving proficiency in more sophisticated mathematics, such as rational numbers and algebra (Gersten et al., 2009a; NCTM, 2006; NRC, 2001; NMAP, 2008). The ROOTS intervention was therefore designed to focus exclusively on whole numbers and build students' deep understanding of what numbers mean, how they operate, and how they are highly interrelated (Rathmell et al., 2011). ROOTS directly focuses on building procedural fluency and conceptual understanding of whole numbers in tandem (Rittle-Johnson et al. 2001; Siegler et al., 2010; Wu, 1999). Research involving ROOTS across multiple methodologically rigorous studies with geographically and demographically diverse cohorts ([redacted] et al., 2020, 2017, 2016a, 2016b; [redacted] et al., 2016, 2019a) including

English learners ([redacted] et al., 2019b) indicate statistically significant positive outcomes (Hedges' g = 0.18-0.81) on a range of mathematics outcome measures.

While previous research has shown ROOTS to be effective as a small group intervention, schools are currently faced with escalating student needs in the general education setting. This changing landscape of U.S. classrooms calls for new, innovative approaches to better support all students, particularly high-need students. Interruptions in learning caused by the COVID-19 pandemic have only compounded existing problems with mathematics achievement, and schools are projected to enter the 2022-23 school year facing an unprecedented number of enrolled students who are significantly behind expected learning targets in mathematics (Lewis & Kuhfeld, 2021). In addition to troubling rates of mathematics achievement, recent data from the National Center for Education Statistics (NCES) reveal that the behavioral health of students is also declining. Public school leaders have seen a marked impact of the pandemic on their students' behavioral development, with 83% of public schools agreeing or strongly agreeing that students' behavioral development has been negatively impacted and 56% reporting that classroom disruptions from student misconduct increased during the 2021-22 school year (NCES, 2022). While the health effects of the pandemic have begun to subside, its impact on student academic achievement and overall well-being are likely to persist. Toward that end, most would agree that **now is the time** for novel solutions that comprehensively address the escalating academic and behavioral needs of all students, especially students who are underserved and students with high needs.

We will address this urgent situation by using an innovative approach to design and empirically test an ***integrated whole class mathematics and behavior program***, M-SENS, that includes effective positive behavior management strategies linked to an existing evidence-based, kindergarten mathematics program (ROOTS) to increase outcomes for all students, especially students with high needs.

To develop M-SENS, we will build on and modify the existing ROOTS intervention in two key ways. First, we will adapt ROOTS to be delivered in a whole class format. The sheer number of students entering kindergarten needing intensive instruction in mathematics limits the feasibility and reach of an approach that provides instruction in small-group instructional formats. This challenge is particularly acute in schools that serve substantial numbers of students who enter kindergarten at risk for learning difficulties in mathematics. Thus, while research suggests ROOTS is effective, by only serving a limited number of students in small groups, the learning needs of a significant number of students are likely left unmet. It is imperative that schools support the development of whole number understanding among all students, including those with high needs. Prior to kindergarten, exposure to mathematical concepts and skills, including counting practice, numeral identification, and comparing number magnitudes, varies widely (Anders et al., 2012; Clements et al., 2003). Typically, children from upper- and middle-class backgrounds enter formal schooling with a significant advantage in mathematics over their economically disadvantaged peers (Starkey et al., 2004). For districts and schools who serve significant numbers of high needs students, providing evidence-based whole number instruction to all students at the start of kindergarten can help mitigate and eliminate the mathematics opportunity gaps that emerge as early as preschool and tend to persist and widen as students encounter increasingly advanced mathematical content throughout the elementary grades (Bodovski & Farkas, 2007; Duncan et al., 2007; Hanich et al., 2001; Judge & Watson, 2011; Morgan et al., 2018; Morgan et al., 2009).

Further, because emerging evidence suggests that students understand and can do more advanced mathematics than what is specified in standards such as the Common Core State Standards for Mathematics (Engel et al., 2013; Engel et al., 2016), delivering ROOTS at the whole class level early in the kindergarten year enables students to work with more challenging material during the second half of kindergarten. Such an approach accelerates student academic achievement and builds a comprehensive foundation for the complex mathematics content encountered in first grade and beyond.

Second, we will integrate a positive behavior support component to comprehensively address student behavioral needs along with their early mathematics achievement. The exclusive focus of ROOTS on mathematics content is reflective of a longstanding trend that schools tend to address student needs through *separate* academic or behavior supports (Kuchle et al., 2015). This approach can be problematic because it fails to acknowledge the inextricable link between behavior and academic performance (Miles & Stipek, 2006). Instead, experts have begun to call for *integrated* systems and interventions that develop student skills in academics and behavior simultaneously (McIntosh & Goodman, 2016).

There are countless benefits to providing integrated academic and behavior supports to students. Integrated supports promote efficiency by maximizing the use of time, personnel, and resources **(**Bradshaw et al., 2009; Domitrovich et al., 2010; Ervin et al., 2006; Kuchle et al., 2015). They are also effective. Integrated supports at the universal level have shown to be effective in increasing academic skill performance and lowering rates of office discipline referrals (McIntosh et al., 2006), reducing off-task behavior and reducing special education participation (Bradshaw et al., 2009), and improving students' social-emotional and behavioral outcomes (Domitrovich et al., 2010). Critically, integrated supports can better support the implementation of classroom instruction. Teachers are tasked with supporting both academic and behavioral needs of students, yet often lack the capacity and resources to do both successfully. A lack of effective classroom management skills is one of the most frequent reasons cited by teachers who leave the field and over half of all public school teachers report a lack of support and training in implementing classroom management strategies (Coalition for Psychology in Schools and Education, 2019; NCES, 2022). Integrated supports are a strategic way to help support teachers with increasing positive behaviors of students while simultaneously effectively meeting their academic needs.

Integrated supports are especially important in the area of mathematics, as difficulties in mathematics frequently coincide with behavioral problems. Kindergarten students' behavioral problems related to attention, task persistence, and organization, are consistently associated with lower mathematics achievement at the end of kindergarten, as well as lagging mathematics growth over the subsequent 5 years (Morgan et al., 2011). There is also evidence to suggest that students with behavioral challenges, specifically externalizing problem behaviors, may not respond as effectively to evidence-based mathematics instruction that does not include integrated behavioral supports as their peers without externalizing problem behaviors (Benz & Powell, 2021).

Similar findings in our own research highlight the need for a behavior support component to support implementation of the ROOTS program. In a recent survey, 78% of teachers delivering ROOTS stated that disruptive student behaviors negatively impacted their ability to effectively deliver the intervention. Teachers also noted that as group size increased, so did the need for behavioral supports. This feedback makes clear that ROOTS can be strengthened by adding a component designed to better support the behavioral needs of students and positive behavior management skills of teachers.

Districts across the nation are struggling to meet the needs of an increasingly high needs student population. Consequently, they are in need of integrated academic and behavior support for students. To address this challenge, M-SENS will bridge the gap between effective early mathematics instruction and positive behavior support and provide an evidence-based approach for kindergarten teachers to comprehensively support the needs of students. M-SENS will provide teachers with a way to provide effective early mathematics instruction while developing positive student behaviors that support student learning, setting the stage for long term success for students.

B. Quality of the Project Design

B.1 Conceptual framework. This project is based on the conceptual framework that M-SENS, when implemented with fidelity, will lead to improved outcomes for both students and teachers as measured by standardized and researcher-developed assessments (see Logic Model in Appendix G). To develop M-SENS, we will rely on the underlying theory of change that systematic instruction on whole number concepts, when implemented in combination with an evidence-based approach for increasing positive behaviors of students, will result in three desired outcomes: (a) accelerated student mathematics achievement, (b) reduced challenging student behaviors in whole-class settings, and (c) increased capacity of teachers to support student early mathematics and behavioral needs.

Three underlying components: (1) evidence-based mathematics instruction (ROOTS), (2) whole class positive behavior supports (The Good Behavior Game), and (3) teacher training and coaching- will work together to yield these three outcomes. The **mathematics component** of M-

SENS will be designed around the same principles that led to significant mathematics learning gains documented in our previous ROOTS studies and lessons learned on previous projects with schools. Using the 50-lesson ROOTS intervention program as a centerpiece, we will strategically modify each lesson for use in a whole class format. The **behavior support component** will draw from The Good Behavior Game (GBG), a classroom management strategy that promotes positive behavior and has shown positive long-term impacts for students (Kellam et al., 2011). The GBG is a classroom behavior management strategy where students are organized into teams that are reinforced for their collective success in displaying positive behaviors and inhibiting inappropriate behavior. This structure helps early learners develop skills such as sitting still, paying attention, collaboration, concern for peers, and completing school work that enable them to fully engage in academic content and provide a foundation for success throughout their schooling. To support implementation of M-SENS, we will also develop and implement an effective **teacher training and coaching model** focused on increasing teacher knowledge and skills of evidence-based mathematics instruction and whole class positive behavior supports.

Table 1. Core Components of M-SENS

Core Component	Detailed Description
1. Evidence-based math instruction	
1a. Whole class ROOTS lessons	50 lessons focused on whole number understanding and following a systematic instructional architecture. Lessons include repeated practice on skills within and across lessons and frequent opportunities for students to engage in mathematical thinking and reasoning.
1b. “Math Practice” worksheets	Daily teacher-guided mathematics practice worksheets that include opportunities for students to engage in independent practice of skills targeted in the lesson.
1c. Note Home	A brief note attached to the “Math Practice” worksheet designed to promote home-school collaboration and math practice at home.
1d. Mathematics models and materials	Mathematics models are designed to build conceptual understanding of abstract concepts. Models include teddy bear counters, base-ten

	blocks, number lines, number and place value charts, numeral cards, and more.
1e. Teacher's Guide	A comprehensive guide for teachers, describing the core components of the program, instructional techniques, and guidelines for implementation.
1f. Check Points	Brief progress monitoring measures designed to help teachers evaluate student response to the program.
2. Whole class positive behavior supports	
2a. Clear expectations	Students will follow a set of up to four straightforward classroom expectations. These expectations help students internalize the positive behaviors that will allow them to be successful during mathematics lessons.
2b. Team membership	Students play the Good Behavior Game in teams that are balanced by behavior and academic ability. Team membership helps students develop relationships with peers who can reinforce expectations and support one another to be successful.
2c. Monitoring positive behavior	Teachers monitor student behavior noting incidents where students exhibit positive behaviors. Students practice monitoring their own behavior and behavior of teammates, enabling teachers and students to reinforce expectations and positive team behaviors.
2d. Positive reinforcement	Positive reinforcement is used to strengthen desired behavior of individuals and the group. This encourages students to repeat productive behaviors, enabling teachers to acknowledge and focus on students' efforts.
3. Teacher training and coaching	
3a. Professional Development workshops	Two teacher workshops will be conducted to promote effective instructional techniques and fidelity to M-SENS, delivered prior to program implementation (Lessons 1-25) and midway through (Lessons 26-30). Workshops will be focused on effective early mathematics instruction and whole class positive behavior supports.
3b. Coaching support	Coaches will provide regular support for teachers throughout program implementation, including 3 formal coaching visits where teachers are observed and feedback is given.

Our team will utilize an iterative **design science approach** (Clements, 2007; [redacted] et al., 2015b) to design and develop M-SENS, concluding with a pilot study focused on demonstrating the promise of the program. Our team has extensive experience in using this methodology across multiple development projects funded by the National Science Foundation (NSF), Institute of Education Science (IES), and Office of Special Education Program (OSEP) (e.g. Chard & Baker, 2004-2007; [redacted] et al., 2009-2012, 2011-2015, 2012-2016; [redacted] et al., 2015-2019; Fien et al., 2012-2015; Strand Cary & [redacted] 2011-2014). These projects have produced eight mathematics intervention programs spanning kindergarten through sixth grade. Critically, this design work has generated programs with evidence of promise such that to date we have been awarded multiple federally funded efficacy trials to formally study the impact of six of our mathematics programs ([redacted] et al., 2008-2012, 2016-2020, 2012-2016; [redacted] et al., 2020-2025; Fien et al., 2016-2020; Strand Cary et al., 2017-2021).

B.2 Goals, Objectives, and Outcomes. We have established a set of ambitious yet attainable goals, objectives, and outcomes that we will achieve over the EIR project period. We will reach our **three primary goals** through three years of school-based implementation beginning in AY 2023-24. Figure 1 shows the timeline and activities for the three research goals.

Figure 1. Project Timeline and Research Activities

Year	Focus	Goal	Winter	Spring	Summer	Fall
Year 1 2023	Develop	1	Develop M-SENS			BLT
Year 2 2024	Develop	1	BLT	Revise M-SENS		
	Test feasibility	2				Feasibility Study
Year 3 2025	Test feasibility	2	Feasibility Study		Revise M-SENS	
	Pilot	3				Pilot Study
Year 4 2026	Pilot	3	Pilot Study	Finalize M-SENS materials		Wait-list control
Year 5 2027	Pilot	3	Wait-list control	Data Analysis & Dissemination		

GOAL 1. We will develop and refine a set of 50 M-SENS lessons that consist of three key components (see Table 1) designed to link the ROOTS intervention program to the GBG in a whole class format. As noted, we propose the use of a design science approach to (a) guide the

development of M-SENS, (b) iteratively refine the program based on teacher feedback, and (c) address shortcomings in current interventions. Initial development of M-SENS will take place throughout winter, spring, and summer of Year 1.

During the 2023-24 AY, we will test lessons and solicit teacher feedback through a Brief Learning Trial (BLT) that will be conducted in four kindergarten classrooms. The BLT study will be conducted to determine how well parts of lessons, individual lessons, and sequences of lessons function for end- users. The goal of the BLT study is to develop an operational version of M-SENS that can be tested in the subsequent feasibility study. Three questions will guide the BLT study: (a) Which lesson features appear to maximize student learning?; (b) How do lesson components work together, and how do lessons function in the whole class setting?; and (c) Which lesson features maximize positive behaviors of students? Following the BLT, we will gather feedback from teachers through the use of surveys, interviews, and focus groups. Project staff will also directly observe the BLT to gather additional information about how the lessons function. During the spring and summer of Year 2, we will revise M-SENS based on teacher input and lessons learned in the BLT.

GOAL 2. We will test the feasibility of M-SENS through a feasibility study that will take place in eight kindergarten classrooms in the 2024-25 AY. The study will allow us to test the feasibility and usability of M-SENS in authentic settings and whether teachers can implement the program as designed. In the study, students will complete approximately 20 lessons, in approximately four weeks of contiguous instruction. The feasibility study will be governed by design science methods and thus allow for ongoing lesson revision. The following questions will guide this work: (a) Do the key components of the program function as intended?, (b) Which lesson features appear to maximize student learning and engagement?, and (c) Are teachers able to implement the lessons as intended within kindergarten classrooms? Central to this study is an iterative development process that allows for ongoing refinement of the program based on empirical data sources, including direct observations, surveys, and teacher interviews and focus groups. When revising the program, the curriculum development team will work with our teacher consultants to examine data patterns, discuss strengths and weaknesses of the current iteration, and plan a course to modify lessons as needed.

GOAL 3. We will pilot M-SENS to test its' promise to improve student outcomes and better understand program implementation. The outcomes study will be a randomized controlled trial experiment across 15 schools and is fully described in section E.

Table 2. Objectives and Outcomes for Key Project Goals

Objective	Outcome
Goal 1. Develop and Refine M-SENS	
Objective 1.1 Create a manualized set of trainings and materials for M-SENS	Outcome 1.1.a A set of 50 whole class M-SENS lessons that integrate ROOTS lessons with whole class positive behavior supports Outcome 1.1.b A fully specified M-SENS teacher training and coaching model Outcome 1.1.c Materials for two full-day teacher training workshops focused on implementing the core components of M-SENS
Objective 1.2 Conduct Brief Learning Trial (BLT)	Outcome 1.2.a School leaders and educators agree to participate in the BLT Outcome 1.2.b Successful BLT completed in four kindergarten classrooms Outcome 1.2.c Feedback is gathered from BLT using direct observation forms, surveys, and teacher interviews and focus groups
Objective 1.3 Refine M-SENS	Outcome 1.3 M-SENS is regularly revised, based on Advisory Board feedback and qualitative data gathered from BLT
Goal 2. Test the Feasibility of M-SENS	
Objective 2.1 Conduct feasibility study	Outcome 2.1.a School leaders and educators agree to participate in the feasibility study Outcome 2.1.b Successful feasibility study completed in eight kindergarten classrooms Outcome 2.1.c Feedback is gathered from feasibility study using direct observation forms, surveys, and teacher interviews and focus groups

Objective 2.2 Refine M-SENS	Outcome 2.2.a M-SENS is regularly revised, based on qualitative data gathered from feasibility study
Goal 3. Pilot M-SENS to Test Effectiveness	
Objective 3.1 Identify 60 kindergarten classrooms to participate in pilot study	Outcome 3.1. School leaders and educators agree to participate in the pilot study for 2 years
Objective 3.2 Randomly assign kindergarten teachers at participating sites to treatment and control conditions	Outcome 3.2 Samples of treatment and control classes have baseline equivalence in key student and teacher characteristics
Objective 3.3 Implement M-SENS in all treatment classes (2025-26 AY)	Outcome 3.3 M-SENS is implemented with a high degree of fidelity and quality in 30 kindergarten classes
Objective 3.4 Assess the impact of M-SENS on student and teacher outcomes	Outcome 3.4 Data on outcomes are collected and analyzed as planned
Objective 3.5 Further refine M-SENS	Outcome 3.5 All core components are regularly refined
Objective 3.6 Implement M-SENS in all treatment and control classes (2026-27 AY)	Outcome 3.6 M-SENS is implemented with a high degree of fidelity and quality in 90 kindergarten classes
Objective 3.7 Publish information about M-SENS and lessons learned	Outcome 3.7 Educators and interested stakeholders are aware of M-SENS

B.3 Extent to which the design will meet the needs of the target population. M-SENS is designed to meet the critical need to improve early mathematics outcomes and increase positive behaviors among high-need kindergarten students. Our primary target population is high-need students who are at risk of mathematics difficulties, including English learners, those with a disability, students living in poverty, and students of color from groups that have been historically underserved. Our project will also serve the kindergarten teachers of these students. For this project, we define "high-need" kindergarten classes as those within school districts where fewer than 30% of students meet proficiency in mathematics as measured by the state mathematics assessment. For districts that have a significant portion of student's at-risk in mathematics, a targeted whole class appoarch represents a more feasible and efficient approach to meeting the needs of their students than targeted intervention alone.

Our initial school district partners for developing and testing M-SENS are Springfield Public Schools (SPS) and Oregon City School District (OCSD). District enrollment is 9,731 total for

SPS and 7,319 for OCSD (Oregon Department of Education, 2021). Students in both districts have had mathematics proficiency levels consistently under 30% with trends across time showing decreased achievement levels. In the Spring of 2021, just 20.1% of fourth grade students in SPS and 18.2% in OCSD were observed to meet proficiency on the fourth grade state assessment of mathematics (Oregon Department of Education, 2021). In the absence of focused efforts, we expect these trends to be further codified due to long term impacts of COVID-19.

This project is appropriate to, and will successfully address, the needs of the target population. First, we will **meet student mathematics needs.** M-SENS will be built on the existing knowledge base of effective mathematics instruction and our previous research experience with effective whole number instruction for high-need kindergarten students. The current ROOTS model to be modified into M-SENS has produced converging results for improving kindergarten student mathematics outcomes. Results across cohorts of previous efficacy studies indicate that students in the ROOTS condition consistently improved from fall to spring at a statistically significant greater rate than students in the control condition on critical distal mathematics outcome measures ([redacted] et al., 2016b, 2017, 2019; [redacted] et al., 2016, 2019a, 2019b; Shanley et al., 2017, 2019). By delivering ROOTS instruction in a whole class format, we will provide grade-appropriate, equitable learning. The program assumes no prior whole number understanding, providing equitable access for all learners. Critically, the instructional architecture of the program is designed to systematically facilitate frequent, high quality instructional interactions to engage students in foundational whole number concepts and skills. Research suggests that instructional interactions sparked through explicit and systematic instruction are critical for all students, including those with or at-risk for mathematics difficulties ([redacted] et al., 2015a; Gersten et al., 2009b). Converging evidence also suggests that at-risk students significantly benefit from instruction that is systematically designed and delivered to include a purposive selection of scaffolded student learning opportunities, visual representations of mathematics ideas, use of key mathematics vocabulary, and engagement in productive mathematical discourse (Baker et al., 2002; Gersten et al., 2009a; NMAP, 2008). ROOTS lessons provide teachers with guidelines for modeling and demonstrating the mathematical concepts and skills students are expected to learn and providing specific academic feedback as students engage in learning activities. The program also provides students with frequent and structured opportunities to work with concrete models of mathematics to build conceptual understanding.

Second, we will **support student behavioral needs** by integrating the core components of the GBG into our program**.** The efficacy of the GBG is widely documented. Teachers who play the GBG in their classroom have reported a reduction in disruptive and off-task behavior, increased time to teach, and greater job satisfaction by the end of the year (Kellam et al., 2011). Approximately 40 interrupted time-series studies exist, showing the nearly immediate reduction in disruptive, aggressive, or inattentive behaviors (Tingstrom et al., 2006). Other studies of the GBG have documented a reduction in off-task behavior as rated by independent observers (Brown, 1993), a reduction in aggressive/disruptive behavior as rated by teachers and peers (Dolan et al., 1993), and a reduction in diagnoses of conduct disorder in fourth grade (Brown et al., 2008). Longer-term benefits include significant effects on aggressive/disruptive behavior through middle school (Kellam et al., 1998; Kellam et al., 1994), a reduction in the rates of antisocial personality disorder, drug and alcohol abuse and dependence, and tobacco use by young adulthood (Kellam et al., 2008), the use of school-based mental health services (Poduska et al., 2008), and the perpetration of violent behavior (Petras et al., 2008). While the decrease in non desired behaviors is important, critically by building a positive set of learning behaviors the GBG also increases student access to the academic content taught in class (Kellam et al., 2011).

Third, we will **incorporate teacher perspectives** to ensure we are effectively meeting the needs of kindergarten teachers**.** As described above, we will continuously solicit teacher feedback throughout the development and testing phases of the current project, through the use of surveys, focus groups, and interviews. Participating teachers will play a critical role in the development of M-SENS, as their feedback will be used to refine and revise the program to ensure it effectively meets the needs of kindergarten teachers serving high needs students.

C. Quality of Project Personnel

Our team, comprised of researchers from the University of Oregon (UO), The University of Texas at Austin (UT), and the RAND Corporation (RAND), has the relevant training and experience to carry out the proposed research. PIs on the UO and UT teams have a long history of obtaining funding through federal agencies (e.g., IES and NSF) to use an iterative design process to successfully develop and test whole-class and small-group mathematics programs that continue to be used in classrooms across the country (e.g., Chard & Baker, 2004-2007; [redacted] et al., 2009-2012, 2011-2015; [redacted] et al., 2015-2019). Additionally, our team has a strong record of securing and conducting follow-up efficacy trials to determine for whom and in what contexts our mathematics programs are most effective (e.g. [redacted] et al., 2008-2012, 2016-2020, 2012-2016, 2020-2025). We have prioritized disseminating results and materials to practitioners and researchers alike to help further the knowledge base of effective mathematics practices for struggling learners. RAND has served as the external evaluator on multiple large scale RCTs (e.g. Baird et al., 2019; [redacted] et al., 2010; [redacted] et al., 2014; Steele et al., 2017) and brings demonstrated experience in intervention research. Our team includes members that are diverse in terms of age, gender, and race and includes persons from groups who have been traditionally underrepresented based on those categories.

The research team's diverse expertise (see resumes in Appendix B), history of collaborative relationships, and experience working with schools to develop and test effective programs will contribute to the project's success. Our senior Leadership Team will be comprised of five individuals with strong expertise in complementary areas and a history of working together to complete projects of a similar scale to the proposed work. [redacted] whose work is focused on integrating academic and behavioral supports, the impact of classroom management on student response to intervention, and outcomes for students at-risk for behavioral difficulties, will serve as the project lead. [redacted] has extensive experience in leadership and management of large scale research studies and currently serves as a Co-PI on multiple federal grants. She will oversee all aspects of the project and will lead development efforts to integrate behavioral components into the ROOTS intervention. [redacted] who specializes in curriculum design and the implementation of evidence-based practices, will oversee development of M-SENS. He currently serves as PI of two NSF-funded projects focused on designing and testing early STEM interventions for at-risk learners and Co-PI on numerous other mathematics intervention projects. [redacted] who has led the development and efficacy testing of mathematics intervention programs spanning the K-6th grade spectrum in both traditional and technology-based formats through 26 federal grants, will oversee all aspects of mathematics assessment for the project. [redacted] will bring experience in the development of early numeracy skills and teacher professional development to oversee modification of the ROOTS intervention to be used in a whole-class setting and the development of teacher training materials. She has served as a curriculum developer, trainer, and mathematics coach on multiple federally-funded mathematics grants. [redacted] specializes in effective classroom behavior management strategies to improve student outcomes and student-teacher relationships and equitable intervention delivery within a multi-tiered positive behavior support framework. She will provide expertise around developing and integrating the positive behavior support component of the program.

[redacted] will lead the RAND evaluation team. He has conducted numerous RCTs including an effectiveness study of Cognitive Tutor Algebra in 150 middle and high schools in seven states; efficacy studies of Cognitive Tutor Geometry, ALEKS, Zearn Math, and the National Summer Learning Project. [redacted] will co-lead the evaluation, overseeing the performance feedback activities and fidelity of implementation analyses. Her prior work includes the Development and Research in Early Math study of instructional coherence in mathematics from preK to grade 3 and numerous federally-funded evaluation studies.

Lastly, we have strategically crafted an Advisory Board for the project that will provide feedback on all aspects of development of M-SENS. Our Advisory Board consists of members with expertise in positive behavior supports and effective math instruction (see Appendix C). We will consult with advisors individually and as a group throughout the project, to suggest refinements to M-SENS materials, review emerging findings, and review reports and manuscripts prepared for publication.

D. Management Plan

We have crafted a management plan that will allow us to achieve all objectives of the proposed project on time and within budget. Throughout the project, ongoing progress will be tracked against our management plan using a cloud-based project monitoring tool. Our project team will meet weekly to monitor progress towards project goals and troubleshoot challenges that arise. Meetings will be led by [redacted] Project Director, who has extensive experience managing large scale research projects.

A fully specified management plan displaying yearly timelines for meeting project goals and objectives is detailed in Appendix J. Overarching project goals include (a) developing M-SENS, (b) testing the feasibility of M-SENS, and (c) piloting M-SENS to test its impact. Objectives, performance measures, and activities with specified start and end dates are provided for each goal. Key project personnel to oversee activities are listed by their initials, with responsibilities divided between staff at UO, UT, and RAND.

E. Quality of the Project Evaluation

E.1. Evaluation Methods Are Designed to Meet WWC Standards Without Reservation. Researchers at the RAND Corporation will serve as independent evaluators, collecting all evaluation measures and performing analyses. The evaluation team, described above, has extensive experience designing and carrying out randomized controlled trials to meet What Works Clearinghouse (WWC) standards without reservation. The outcomes study will be a randomized controlled trial experiment that will address the following research questions:

- **RQ1.** What is the impact of M-SENS on student mathematics outcomes?
- **RQ2.** What is the impact of M-SENS on student behavior outcomes?
- **RQ3.** Does the M-SENS program result in increased capacity of teachers to support student early mathematics and behavioral needs?
- **RQ4a.** To what degree is M-SENS implemented with fidelity?
- **RQ4b.** What are the barriers and facilitators of implementation?

RAND will enroll 15 schools with an estimated four kindergarten classrooms per school and 21 students per class. Blocking on school, half of the classes will be randomized to implement M-SENS, and the other half to serve as business-as-usual controls. The experiment will occur during the 2025-26 school year. The following year, both groups of classrooms will implement M-SENS. In this design, an estimated 630 students will receive M-SENS during the experiment and an additional 1,260 after the experiment, for a total of 1,890 students receiving the program.

For the confirmatory research question on the effects of M-SENS on mathematics achievement (RQ1), RAND will administer the *Screener for Early Number Sense (SENS;* Jordan et al., 2020) as both a baseline and outcome measure. SENS is an assessment of number, number relations, and number operations for students in prekindergarten, kindergarten, and Grade 1. We chose SENS for its validity as an externally developed alternative to the very similar internally developed *ROOTS Assessment of Early Numeracy Skills (RAENS)*. ROOTS produced a standardized effect of 0.75 on RAENS in the original efficacy project ([redacted] et al., 2020). For kindergarten students, SENS has demonstrated internal consistency reliability of 0.93, test-retest reliability of 0.95, and predictive validity of 0.79 toward an externally developed, standardized measure of whole number understanding, the *Test of` Early Mathematics Ability-Third Edition (TEMA-3*) (Jordan, in press).

For an additional exploratory mathematics outcome, RAND will administer the *Assessing Student Proficiency in Early Number Sense* (*ASPENS*; [redacted] et al., 2011a). ASPENS consists of three curriculum-based measures validated for screening and progress monitoring in kindergarten mathematics. Each 1-minute fluency-based measure assesses an important aspect of early numeracy proficiency, including number identification, magnitude comparison, and strategic counting (missing number). ASPENS has moderate to high test-retest reliability (.74 to .85), concurrent validity (0.60) and predictive validity (0.69); validities were measured by correlations to *TEMA-3*.

For exploration of the effect of M-SENS on the behavioral outcomes (RQ2), RAND will administer the *Teacher Observation of Classroom Adaptation—Checklist (TOCA-C;* Koth et al., 2009) as both baseline and outcome measures. TOCA-C provides indices of children's disruptive behavior (9 items), concentration problems (7 items), and prosocial behavior (5 items). Teachers read statements about a child (e.g., "pays attention") and endorse items on a 6-point scale (never to always). The TOCA-C scales are internally consistent ($\alpha>0.86$) and invariant across gender, race, and age (Koth et al., 2009); sensitive to change in universal preventive interventions (Bradshaw et al., 2012); demonstrate divergent validity, concurrent validity, and test-retest reliability (Kourkounasiou & Skordilis, 2014); and longitudinal measurement invariance (Troncoso & Humphrey, 2021). The study will explore effects on all three scales.

Our outcomes research questions address post-intervention differences in mathematics and behavioral outcomes between M-SENS students and their control group peers. These questions will be addressed with the following statistical model:

$$Y_{ijk} = \beta_0 + \beta_1 T_{jk} + \boldsymbol{X}_{ijk}\boldsymbol{\beta}_2 + \boldsymbol{W}_{jk}\boldsymbol{\beta}_3 + \alpha_j + \varepsilon_{ij}$$

where Y_{ijk} denotes the outcome score for student i in classroom j, in school k, T_{jk} is an indicator that is 1 if a classroom was randomized to implement M-SENS and 0 otherwise, $\boldsymbol{X}_{ijk}$ denotes a vector of individual and group-level covariates, mean-centered as appropriate, and $\boldsymbol{w}_k$ is a vector of school indicators accounting for the blocked randomization design. We intend to include a rich set of covariates in $\boldsymbol{x}_{ijk}$, including student baseline measures, potential moderators, and classroom aggregates to improve model precision by reducing unexplained variance in the outcome. We will account for the nested nature of the data by clustering standard errors at the school level using cluster-robust variance estimation with small-sample corrections

(Pustejovsky & Tipton, 2015). The parameter of interest is β_1, the difference in expected outcomes for M-SENS classes compared to the control group.

The study is powered to detect a standardized effect of 0.25 or larger on the confirmatory mathematics outcome. This is much smaller than the previously-achieved effect of 0.75 on RAENS ([redacted] et al., 2020), allowing for smaller effects due to differences such as whole-class vs. small-group instruction and the use of an externally-developed mathematics measure. Power was calculated using the PowerUp! tool (Dong & Maynard, 2013), using the sample sizes noted above and setting other parameters based on empirical data from the original ROOTS study and similar studies of early-grade small group interventions: an ICC of .159, 60 percent of the variance of student-level outcomes explained by student baseline covariates, and 40 percent of class-level variance explained by classroom covariates and block indicators ([redacted] et al., 2016b, 2011b; [redacted] et al., 2015b).

E.2. Evaluation Methods Will Provide Performance Feedback and Periodic Assessment of Progress. In the first three years of the grant, the RAND evaluation team will document how M-SENS is designed and modified during feasibility testing. The team will draw upon annual interviews with program staff, participation in regular check-in meetings, and review of documentation. These findings will help to inform the evaluation activities and shed light on the process of development and feasibility testing. In addition, the RAND team will provide formative feedback to the UO team, drawing upon these interview data, along with independent analyses of data collected by program staff (including surveys of teachers, as described below).

E.3. Key Project Components, Mediators, Outcomes, and Measurable Implementation Threshold. To support our outcomes analysis, we will also analyze fidelity of implementation. We will measure the implementation of M-SENS components with three primary types of data:

1) teacher-reported instructional logs of M-SENS lessons; 2) coach fidelity forms; and 2) teacher surveys. These data will be used to analyzed to address RQs 3, 4a, and 4b.

Instructional Logs. Over the course of the intervention, the teachers will complete weekly Instructional Logs that track the date when M-SENS lessons were completed, the duration of the lesson, and the students who were present. We will analyze these items to understand the extent to which the dosage of M-SENS was consistent across sites and students. We will use this information to define a minimum threshold for implementation and confirm that lessons were implemented on schedule.

Coaching fidelity forms. During the three coaching visits conducted at each M-SENS classroom, coaches will complete fidelity forms based on their observations of instruction. This form will assess whether core components of M-SENS are implemented as expected. We will use this information to assess the consistency of implementation across sites and to document any instructional adjustments or refinements.

Teacher surveys. We will administer two surveys to each teacher involved in the M-SENS pilot. Because teachers are the primary implementers of M-SENS, their individual characteristics and perceptions of the program are key factors that may explain variation in implementation and outcomes. The first survey will be administered at the conclusion of M-SENS implementation and will measure teacher demographic characteristics (e.g., race/ethnicity, age, gender, teaching experience, education, and possible areas of specialization); characteristics of kindergarten classrooms (e.g., class size, number of students at-risk for MLD, number of ELs, and the content and amount of core mathematics instruction provided); information about any mathematics intervention supports beyond core mathematics instruction received by students; perceptions of the social validity of M-SENS (including, core components, goals, procedures, and desired student outcomes); experiences with the M-SENS PD supports; and the types of and rationale behind any instructional adjustments and refinements of M-SENS lessons. This survey will be used to understand the classroom contexts to which M-SENS will be added. A second survey will be administered both pre- and post- M-SENS implementation. This survey will assess teacher's perceived capacity to support student early mathematics and behavioral needs and will ask teachers to rate the extent to which they feel prepared to foster positive learning behaviors among students, address challenging student behaviors in a whole-class setting, and provide effective mathematics instruction to promote early number sense.

Measurable Threshold for Acceptable Implementation and Use of Implementation Variables. We will employ thresholds for acceptable implementation. First, all teachers must deliver at least 90% of the M-SENS lessons to students in the treatment group. We will determine whether this threshold is met from information collected in the teachers' instructional logs. We will support this assessment with data from coaching forms, which measure the fidelity of implementation during informal observations of instruction. Additional implementation variables such as additional math intervention supports or amount of coaching support provided to teachers will be derived from the survey measures. These variables are not intended to capture a minimum threshold of implementation, but rather key aspects of potential variation in the implementation process. Along with fidelity assessment, these variables will be used to explore such topics as the relationship between implementation and outcomes, factors that predict fidelity, and potential obstacles and enablers of implementation.