Young Academic Music and Computational Thinking

Contents: **Page:**

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National Significance

Young Academic Music and Computational Thinking will be a scalable program including curriculum and teacher professional development for high-need kindergarten students in rural and high-need urban school districts. High-need refers to students from minority groups, low socioeconomic classification (SEC) groups, English learners, and students with disabilities.

Young Academic Music and Computational Thinking for Kindergarten is an early phase grant proposal addressing absolute priorities 1, 2, and 3, and competitive preference priority of expanding access to rigorous computer science coursework for traditionally underrepresented students. The goal of *Young Academic Music and Computational Thinking for Kindergarten* is to improve and innovate on math, music and computational thinking (CT) instruction in kindergarten. We will accomplish this through an innovative approach to field-initiated development. Our goals include the following: 1) Create a high-quality, comprehensive, field-tested mathematics-through-music curriculum that is aligned to state standards with implementation supports by Fall 2021; 2) Implementation with fidelity results in improved child outcomes in music, mathematics, computational thinking, and social emotional learning during the 2021-22 and 2022-23 school years; and 3) Use of embedded professional development builds the capacity of district personnel to sustain work following grant period.

We propose a new way of learning early STEM skills by utilizing rhythm and music notation instructional activities as the platform for early numeracy skills and the basic elements of computer coding—algorithm, sequence, loop, branch, and debug—for diverse groups of high-need urban and rural kindergarten students. Utilizing an iterative co-design process that takes advantage of the diverse expertise of all our partners, we will implement a usability/pilot testing process that involves developing content, identifying assessments, planning technology tools, testing lessons and with each cycle, we refine the process. We will conduct a total of 4 pilots (4 teachers and 80 high-need students) to understand what works and what is challenging for teachers with little training in music and technology.

The creation of a novel curriculum for teaching math and CT through music develops early numeracy and CT skills must be accompanied by appropriate teacher training to address the challenges and discomfort elementary teachers report when teaching math and science (Bursal & Paznokas, 2006; Murphy & Mancini-Samuelson, 2012). Professional development for teachers will help them move beyond traditional teaching practices to more active learning practices (Anderson et al., 2011). Teachers will learn and practice engaging students in music activities, discussion to help students connect music to mathematics and coding, and processes that promote higher-order thinking and collaboration. Professional development will include both content and content-specific pedagogies for engaging a diverse group of students.

The final curriculum will be tested through a rigorous evaluation design that meets WWC standards to measure the main student outcomes of mathematics and social emotional competence through confirmatory analysis as well as the secondary outcomes of computational thinking and music through exploratory analysis. Evaluation of the curriculum will take place in a randomized control trial of 35 high-need rural classrooms in Austin, TX and 35 high-need schools in New York City, involving approximately 1000 kindergarten students across two years of data collection.

Science, Technology, Engineering, and Mathematics (STEM) knowledge is a growing requirement for anyone entering the workforce (National Science Board, 2018). A STEM-ready workforce creates opportunity for better jobs and increased prosperity across our country, especially for traditionally underrepresented youth and young people from rural areas. Despite the growing need for a STEM-ready workforce in our country, the U.S. Department of Education reports "persistent inequities in access, participation, and success in STEM subjects that exist along racial, socioeconomic, gender, and geographic lines, as well as among students with disabilities" (U. S. Department of Education, 2016,). The disparities in STEM education are a threat to our ability to close education and poverty gaps.

Decisions about pursuing a career in STEM are determined by the sixth grade, yet young elementary students have very little exposure to STEM content, little opportunity to explore

interests in STEM, and are therefore likely not on a trajectory to STEM fields (Gerlach, 2015; NRC, 2012). The lack of STEM education in rural areas is especially troubling as data show that rural schools are not meeting student performance benchmarks in mathematics and science. Rural children from lower socioeconomic status families often start kindergarten with lower mathematics achievement and make less progress during elementary and middle school than their suburban and urban peers (Graham & Provost, 2012). Rural schools are often challenged in education improvement efforts by geographic isolation, fewer numbers of experienced teachers, and fewer resources (Boyer, 2006).

Rural Texas. Approximately 50% of Texas children (and 60% of children from low-income backgrounds) do not meet minimum levels on kindergarten readiness measures, e.g., many children, on the first day of kindergarten, do not meet numeracy standards such as counting a set of 10 items, adding or subtracting several items to or from a set, or naming common shapes (E3 Alliance, 2012; Texas Prekindergarten Guidelines, 2015).

New York City. STEM programs are very scarce in New York City's economically challenged urban communities (New York Equity Coalition, 2018). While New York City is addressing this problem with initiatives like 'AP for ALL,' providing Advanced Placement courses to 75% of high school students, the lack of STEM curricula should be addressed well before high school. In order to prepare students for rigorous coursework in middle and high school, all elementary students should have opportunity to access a STEM curriculum with supports and resources to ensure success.

Promising New Strategies

To address the need for increased STEM exposure to young students, especially traditionally underrepresented students and students in rural areas, we are designing an integrated music, mathematics, and computational thinking curriculum that teachers can implement in inclusive classrooms of cognitively, linguistically, and culturally diverse students. Our novel integrated curriculum, *Young Academic Music and Computational Thinking* begins with guided musical play activities to stimulate natural curiosity and exploration in the academic areas of

mathematics, music, and computational thinking. Because a large body of evidence suggests that strong math skills and computational thinking in young children are a powerful predictor of future academic success (Bers, 2018; Samuels, 2017), we focus on developing early mathematics skills with music instructional activities and tasks carefully aligned to the basic components of coding (algorithm, sequence, loop, branch, and debug). By starting with music and play, we create a less intimidating environment that is more accessible to all learners, including students with disabilities, ELs, or other youth who have struggled in more traditional classroom settings, to participate in a STEM curriculum (U.S. Department of Education, OET, 2016).

With easy to follow lesson plans, video demonstrations, and implementation guides, teachers can bring music into the kindergarten classroom to teach beginning mathematics skills and computational thinking.

Project Design and Management Plan

Young Academic Music and Computational Thinking Project goals, objectives, and outcomes are clearly specified and measurable, with the overall goal of student achievement in mathematics, computational thinking, music, and social and emotional learning. The table below clearly identifies tasks, timelines and project personnel responsible for each task (Table 1).

Table 1: EIR Grant Goals and Objectives, Activities, Person(s) Responsible, Timeline, Indicators, Outcomes

Goal 1: Create high-quality, comprehensive, field-tested curriculum that is aligned to state standards with implementation supports by Fall 2021					
Objective 1: Curriculum is aligned to music, mathematics, and technology standards					
Activities	*Person(s) Responsible*	*Timeline*	*Short-term Outcomes/Evaluation*	*Changes based on Evaluation*	*Long-term Outcomes/ Evaluation*
1. Teachers (Roslyn Haber and Timothy Bellavia) and PIs meet with mathematics and music experts to review existing curriculum (**Weekly** meetings with PIs, Project Manager, Trainers and **Bimonthly** meetings with experts)	PIs, Project Manager, Timothy Bellavia, Endre Balogh, Charlie Patton	October 1 through December 15, 2019 Fall 2022 through Spring 2024	Teachers, experts and PIs agree the curriculum covers key topics and meets standards (*meeting minutes, lesson plans, curriculum alignment matrix*)	Lesson plans are complete with objectives, identified materials, formative and summative assessments (*Lesson Plans, formative and summative assessments*)	Increased number of teachers who implement *Young Academic Music* (YAM) with fidelity to improve child outcomes in music, mathematics, and social emotional learning (number of teachers obtaining YAM curriculum for WestEd)
2. Teachers (Roslyn Haber and Timothy Bellavia) and PIs meet with mathematics, music, and computer programming experts to design integrated curriculum (**Weekly** meetings with PIs, Project Manager, Trainers and **Bimonthly** meetings with experts)	PIs, Project Manager, Roslyn Haber, Timothy Bellavia, Endre Balogh, Charlie Patton,	October 1 through February 1, 2020	Teachers, experts and PIs agree the extended curriculum meets standards and adequately addresses computational thinking (*meeting minutes, lesson plans, curricular alignment matrix*)	Lesson plans are complete with objectives, identified materials, formative and summative assessments (*Lesson Plans, formative and summative assessments*)	Increased number of teachers who implement *Young Academic Music* (YAM) with fidelity to improve child outcomes in music, mathematics, social emotional learning, and computational thinking (number of teachers obtaining YAM curriculum for WestEd)
3. Design professional development for teachers implementing the curriculum in pilot tests (**Weekly**	PIs, project coordinator, computer programmer, videographer	October 1 through February 1, 2020	Customized Professional Development programs (*PD program plan, materials, schedule, videos*)	Improved Professional Development (*teachers' PD session evaluations*)	High quality Professional Development materials tested, evaluated, improved and ready for dissemination (Materials and video)

meetings with PIs, Project Manager, Trainers and **Bimonthly** meetings with experts)					
Objective 2: Pilot tests of all features of the curriculum are carried out to result in one complete draft to be piloted in 4 inclusive classrooms					
Activities	*Person(s) Responsible*	*Timeline*	*Short-term Outcomes*	*Changes based on evaluation*	*Long-term Outcomes/ Evaluation*
1. Recruit 4 teachers to implement 2 cycles of pilot testing	PI, Project Coordinator	October 2019			
2. Professional Development Workshop for pilot test teachers	PI, 4 teachers,	January 2020	Teachers implement curriculum with fidelity *(FOI measure, survey)*	Teachers report curriculum is user-friendly understandable (survey)	High quality Professional Development materials tested, evaluated, improved and ready for dissemination (*Materials and video*)
3. Determine a schedule and plan for 2 cycles of pilot testing curriculum	PI, Daniel's Music Foundation, Project Manager	October 1 through November 15, 2019	Schedule *(schedule)*	Refined Schedule (*schedule changes*)	Pilot Test Results *(surveys and curriculum)*
4. Pilot tests of curriculum are carried out in 2 cycles with bi-monthly evaluation and assessment meetings	PI, Project Coordinator, Daniel's Music Foundation, Teachers	January 2020 through May 2020 and September 2020 through December 2020	Pilot data exists for all aspects of curriculum (*observational data, survey, meeting minutes*)	Data from pilots are analyzed and improvements are made to curriculum (*formative data*)	Teachers and content experts report the curriculum meets the needs of teachers (*survey and meeting minutes*)
Objective 3: Final curriculum and professional development workshop addresses the needs of kindergarten teachers in high need classrooms with cognitively, linguistically, and culturally diverse students in urban and rural school districts					
Activities	*Person(s) Responsible*	*Timeline*	*Short-term Outcomes/Evaluation*	*Changes based on evaluation*	*Long-term Outcomes/ Evaluation*

1. Professional Development Workshop and Support Materials are approved by teachers and experts	Program Manager, PIs, Experts, and Pilot Teachers	Summer 2021	Comprehensive Integrated Curriculum Professional Development is approved for RCT 1	Professional Development and Supports are evaluated after RCT 1	Improved Professional Development and Support Materials
2. Curriculum and Materials are approved by teachers and experts	Program Director, PIs, Experts, and Pilot Teachers	Summer 2021	Comprehensive Integrated Curriculum is approved for RCT 1	Curriculum and Materials are evaluated after RCT 1	Improved Curriculum and Materials
Objective 4: Curriculum, implementation videos, professional development workshop and supports are publicly available					
Activities	*Person(s) Responsible*	*Timeline*	*Short-term Outcomes/Evaluation*	*Changes based on evaluation*	*Long-term Outcomes/Evaluation*
1. Curriculum resources and materials are professionally published and disseminated	Program Director, WestEd, Herbie Hancock Institute	Year 4 and 5	Dissemination Rates ((how many kits are disseminated)	Increase the number of dissemination centers	Increased number of kindergarten students exposed to STEM, music, and computational thinking
Goal 2: Implementation with fidelity results in improved child outcomes in mathematics and social emotional learning (confirmatory); computational thinking and music (exploratory) for school years 2021-22 (Cohort 1) and 2022-23 (Cohort 2) *Refer to description of Evaluation Plan: Summative evaluation phase and Table 2.*					
Goal 3: Use embedded professional development to build capacity of district personnel to sustain work following grant period. (Train coaches at State and National Centers to implement curriculum and support teacher development).					
Objective 1: Support curriculum implementation with professional development					
Activities	*Person(s) Responsible*	*Timeline*	*Short-term Outcomes/Evaluation*	*Changes based on Evaluation*	*Long-term Outcomes/ Evaluation*
1. Identify State Centers	Program Manager, PIs, Training Teachers	Year 4 and 5	Curriculum and Professional Development is Nationally available	Increase the number of participating centers	Program Director, PIs, Training Teachers

2. Identify National Centers	Program Manager, PIs,	Year 4 and 5	Curriculum and Professional Development is Nationally available	Increase the number of participating centers	Program Director, PIs, Training Teachers

Conceptual Framework

Courey, Balogh, Siker, & Paik (2012) examined the effects of using music notation to teach beginning fraction concepts to diverse groups of third-grade students. Results demonstrated significant differences between experimental and comparison students' music and fraction concepts, and fraction computation at posttest with large effect sizes. Students who came to instruction with less fraction knowledge responded well to instruction and produced posttest scores similar to their higher achieving peers.

Courey et. al. utilized a semiotic approach to instructional design by creating an environment filled with multimodal opportunities for students to make conceptual connections between properties inherent in fraction representations and fraction symbols. Because an effective learning environment should include opportunity and strategically selected tools for students to make connections and construct meaning (Abrahamson, 2009), we chose music notation as the initial medium through which students could grapple with their emerging understanding of beginning fraction concepts for two reasons. First, we noticed that young students who were learning to play an instrument for the first time seemed to have little difficulty adding and subtracting the value of music notes. Second, utilizing music notation enabled us to create a multimodal environment for students to experience the proportional values inherent in music notes. Students read the notes, called the notes by name, clapped and drummed the value of the notes.

We employed components of the Kodaly system of music education (Hurwitz, Wolff, Bortnick, & Kokas, 1975). This system is especially designed for young children as it promotes experiential learning via several learning modalities (i.e., visual, auditory and kinesthetic) (Gault, 2005). The following components of sound instructional practices were incorporated in each lesson: teacher modeling guided practice, independent practice and cumulative review (Scarlato & Burr, 2002). Azaryahu, Courey, Elkoshi, & Adi-Japha (in review) replicated and extended Courey, Balogh, Siker, & Paik (2012) with similar results. We have a compelling reason to view music instruction as an integral part of the elementary curriculum, due to its utility in teaching

beginning fraction concepts and related fraction computation to elementary students. This converging body of evidence encouraged us to develop a theoretically similar curriculum for kindergarten students using music to teach mathematics and computational thinking.

Mathematics and music are related in the brain from very early in life (Geist, Geist, & Kuznik, 2012; Linder, Powers-Costello, & Stegelin 2011; Zentner & Eerola, 2010) Musical elements like steady beat, rhythm, tempo and melody possess inherent mathematical principles such as spatial properties, sequencing, counting, patterning, and one-to-one correspondence - the very concepts included in the Common Core State Standards as well as CT and coding (Geist, Geist, & Kuznik, 2012; Bers, 2010). Additionally, An & Tillman (2015) found bilingual elementary students transferred understanding of patterns and proportions found in music to a mathematical context. Learning to relate patterns and proportion to pleasant sounding musical arrangements led to positive dispositions towards mathematics. If dispositions toward math could be improved by using music, perhaps bringing coding and music into the curriculum could predispose these young students to a digital environment.

We are currently examining the effects of *Young Academic Music* on the development of the following three areas of mathematics: 1) number concepts and quantities; 2) number relationships, and operations; and 3) Patterns. Utilizing the principles of Universal Design for Learning (UDL) ensures that learning is accessible to students who need a variety of ways to engage with the lesson and demonstrate what they have learned (Rose & Meyer, 2002). We view teachers as learning facilitators and we utilize a variety of tools and strategies to remove barriers, create access to curriculum and provide rich educational opportunities. Kindergarten students with disabilities learn to read musical notes and perform basic rhythmic patterns through clapping and drumming. They work toward adding musical notes together to produce numbers and patterns, and create addition/subtraction problems with musical notes. These music notes come alive as animated objects that engage students with a fun concrete representation of the value of the note. Activities are designed to reinforce note values by engaging with animated note dolls, drumming rhythms based on the value of a whole note, and adding and subtracting

numbers as these values relate to musical notes and rhythms. The preliminary success of these lessons encouraged us to extend the curriculum to include computational thinking through computer programming (Please see Logic Model in G).

To provide a more rich and in-depth curriculum, we introduce basic computer programming as an embodied learning environment where students can experiment, create, and connect knowledge in a social environment (Kafai & Burke, 2014). Research demonstrates how young children can move between music notes, number symbols and gesturing to develop understanding of abstract concepts (Radford, 2003; Presmeg, 2006). Building on Papert's conceptualization of computational thinking and technology, we view coding as a way to help students learn by making, creating, questioning, and playing (Papert, 2000). To truly create a novel music and STEM curriculum, we need the teaching and learning of programming to be integrated across the curriculum so that it becomes a part of everyday classwork. As students make connections between musical rhythms and different magnitudes and patterns of numbers, we integrate coding to reinforce learning, create varied perspectives on what is being learned, and as a way to document and share learning trajectories (Bers & Horn, 2010).

This multimodal approach to early music, math, and computational thinking instruction encourages a deeper understanding of mathematical reasoning because students are introduced to number, pattern, and problem solving concepts in fun and engaging ways. Computational thinking is a vehicle for refining understanding and expanding concepts across the curriculum within a safe social learning environment. (Kafai & Burke, 2014). Through this spiraled curriculum of music, mathematics, and CT, we are creating a safe and shared learning environment in which students can physically and virtually interact with, create and improve music, math and computer programming understanding. Students will progress through the curriculum working in pairs because student motivation and troubleshooting persistence increases significantly when they work in pairs (Kafai, & Burke, 2014). Working in pairs requires students to communicate and collaborate. In turn, these ongoing interactions to achieve a common goal is likely to improve students' social and emotional learning (Bers & Horn, 2010)

We look to ScratchJr to begin coding because it is free digital coding playground that can engage diverse groups of children with varied levels of interests and achievement (Bers and Resnick, 2015). This curriculum and professional development for elementary teachers to implement this novel curriculum, requires us to challenge teachers to have high expectations for all students, including English Language Learners (ELLs) and students with disabilities, and intentionally focus on how to support all students. Because we aim to address the needs of all learners in inclusive classrooms, we look to ScratchJr as an accessible coding program platform. ScratchJr is designed to address the following ideological and ethical principles that allow access to STEM for all students: low floor (students at any ability level can utilize the program to increase learning); high ceiling (gifted students and students who are proficient in music and/or math) have opportunity to move beyond grade level objectives and possibly create a better curriculum and learning trajectory. By incorporating coding and CT, we are not only creating a low floor for struggling students, and a high floor for higher achieving students, we are allowing for wide walls in a classroom, virtual and real, for expanding what we think we know about teaching and learning in kindergarten (Kafai & Burke, 2014)

As we extend this curriculum, learning activities will be designed to provide students with opportunities to elaborate their ideas, to make their reasoning explicit through the use of why and how questions, and to make abstract concepts more concrete by using visuals and interactive materials (Grossman, Schoenfeld, & Lee, 2005). Professional Development for teachers implementing this novel curriculum will focus on training teachers to build connections across music, mathematics, and computational thinking content.

Professional Development. Teachers will have the opportunity to practice implementing lessons that elicit student engagement, reasoning and discussion in the math classroom. In early inclusion classrooms, teachers have difficulty assessing students' developmental levels of understanding and differentiating instruction to meet students learning needs. In turn, we will discuss how teachers can learn to address what makes concepts difficult to comprehend and how to provide scaffolding when students struggle to formulate ideas and understanding. We

combine elements of direct instruction with more student-centered, constructivist teaching strategies so teachers can model how to teach children to solve problems more conceptually. Van Garderen, Scheuermann, Jackson, & Hampton (2008) explain that no one teacher, no matter how qualified, has all the pedagogical expertise and content knowledge required to meet the needs of ALL students. To address this challenge, we will design instructional progressions that; a) enable students with learning and language challenges to develop multiple ways of building representations for math concepts; b) multiple resources for accessing conceptual content; and c) multiple opportunities and output methods for students to demonstrate their understanding. Through well-designed lessons and varied pedagogical practices, students will develop a mathematical mindset and learn to see math in the world around them.

WestEd Product Development. This product will be developed into a web-based, downloadable teacher's guide with accompanying downloadable teacher tools and training video. The product will consist of 18, 30-minute lessons, downloadable materials and two 10-minute videos, one which overviews the product and research that supports the curriculum along with a demonstration video of the curriculum, materials and methods for delivery. Throughout years 1-3 of the project, production staff will periodically interface with researchers to address any post-research production issues.

The curriculum will include a 20-30 page introduction of background information, including the research base and project findings, 18 lesson plans that include a list of lesson objectives, a list of materials needed to conduct the lesson, description of the prior knowledge and experiences that students should possess to successfully participate in the lesson, and written procedures to provide the instruction. The written lessons will contain hyperlinks to the necessary downloadable materials that need to be copied onto hard stock for use in the instruction, and hyperlinks to video clips needed throughout the lesson. The materials list will include the links to the downloadable materials and description of any other items that need to be gathered to support the lesson, and instructions for their use (See Appendix I) for example of a similarly formatted lesson). The guide will include up to 50 pages of lesson materials that are

used or can be downloaded for use with the lessons. This electronically produced curriculum will be produced in year 4 and made available at the end of year 4 and throughout year 5 of the project.

The first of two videos will describe the rationale for the curriculum along with the theoretical and research base for the material. This video will interview the researchers in the project and teachers of the curriculum, while showing lessons in action with students. The second video provides a narrated description and visualization of the curriculum lesson plans, materials, and a demonstration of how to utilize these products in a sample lesson.

The Herbie Hancock Institute (HHI) will create additional two types of videos for the project. First, they will create videos depicting teachers overcoming implementation challenges and struggling student video with anticipated misconceptions and behavioral challenges. Second, HHI will create music note video with animated music notes displayed as simple songs like Mary Had a Little Lamb for students to follow along.

Feedback and Continuous Improvement

Our project design includes several strategies for feedback and continuous improvement. Weekly meetings during the first year of the project are the venue for our team needs to engage in cycles of exploration using a variety of sources to plan, assess, and evaluate the developing curriculum. Using multiple data sources to analyze student, educator, and system performance will help create a more balanced and comprehensive picture of curriculum and professional development. Experts will discus, examine, evaluate, and provide feedback on the development process during bi-monthly meetings in the first year. Our external evaluator, SRI, will document the YAM program developers' work to provide guidance on effective strategies suitable for replication or testing across multiple contexts and with diverse populations. This will be done through artifact analysis (e.g., PD training agenda and materials), teacher and administrator interviews and surveys, observations of training, and site visits. Project personnel will also give each other feedback, working closely together with SRI throughout the development, pilot, and implementation phases of the project. Project personnel and SRI will continually assess progress,

discuss process improvements, and assign responsibility for making them.

Management Plan Personnel.

The projects team consists of experts in the fields of mathematics, music and computer programming who have worked together on research projects and program improvement projects. Personnel roles are clearly defined. Personnel background and responsibilities are listed below.

Susan Courey, Ph.D., Co-PI (20% FTE) is Early Childhood General and Special Education Program Chair, Birth to Grade 2, at Touro Graduate School of Education. Dr. Courey will direct curriculum development and teacher professional development planning and implementation. She will also assist Dr. Haber with ensuring adherence to timelines, budgets, and milestones.

Sarah Powell, Ph.D. Co-PI (5% Year 1 and 2, 10% Year 3 FTE) is an Associate Professor in the Department of Special Education at the University of Texas, Austin. Her research includes peer tutoring, word-problem solving, mathematics writing, and the symbols and vocabulary within mathematics. Dr. Powell will work with Dr. Courey on curriculum development and teacher Professional Development planning and implementation.

Roslyn Haber, Ed.D. (50% FTE, Project Manager and Trainer) has 35 years experience with the NYC DOE as a teacher, evaluator, and administrator. She is a Co-Author of Language Assessment Battery (instrument for the Federal Court Case *Jose P. versus Mills* to determine dominant language for instruction). Dr. Haber has been an adjunct instructor at Adelphi University and Fordham University. Dr. Haber is currently working with Dr. Courey on the development and implementation of *Young Academic Music*. Dr. Haber will oversee all project activities, manage the project, and train teacher during professional development sessions.

Timothy Bellavia, M.F.A. (20% FTE, Trainer) is an Assistant Professor of the Graduate School of Education at Touro College and University System in New York City. He is an award winning children's author, illustrator, and educator and has collaborated with Sesame

Workshop and other music and drama professionals. He is currently working with Dr. Courey on the development and implementation of *Young Academic Music*.

Endre Balogh, M.A. (Academic Music) is the co-founder of Toones Academic Music and professional performer (saxophone, flute) degree from Trade Union of Hungarian Musicians in Budapest, Hungary. Mr. Balogh is responsible for maintaining the integrity of the music instruction in the integrated curriculum.

Charles Patton, Ph.D. (Technology and Mathematics consultant) is a mathematician and former SRI senior scientist with an extensive track record of innovation in mathematics learning technologies will serve as a consultant on the accuracy and coherence of the mathematics, music, and computational thinking through the curriculum.

Elina Lampert-Shepel, Ed.D. (5% FTE Mediational Means and Reflective Practices) is a teacher educator and Chair of the Childhood General and Special Education Program, Grades 1 to 6 in the Graduate School of Education at Touro College. Dr. Lampert-Shepel is responsible for ensuring that the Cultural–historical psychology of Vygotsky, which informs the conceptual framework of the music, mathematics, and computational thinking curriculum, drives the design of teacher professional development.

Brenda Strassfeld, Ph.D. (5% FTE Mathematics Pedagogy) is a mathematics educator and Chair of the Mathematics Education Program in the Graduate School of Education at Touro College. Her research concerns teachers' and students' attitudes and beliefs regarding teaching and learning mathematics. Dr. Strassfeld is responsible for informing the design of professional development for teachers implementing the mathematics, music, and computational curriculum, including reviewing available literature on effective classroom practices and professional development models

Dissemination and Support.

The curriculum will be disseminated through a series of announcements in appropriate special education, music and math/STEM publications, as well as at professional conferences in special education, music and math/STEM. Flyers will be electronically disseminated to email

lists of special education administrators, special education teachers, approved private special education facilities, music educators and math/stem educators. This will occur at the end of year 4 and throughout year 5. Project personnel will recruit state regional and national educational information centers to disseminate curriculum and professional development materials. Further, the Herbie Hancock Institute and WestEd fully support the project and will make all resources and materials available on their websites.

Project Evaluation

SRI International will conduct an independent evaluation of the YAM program's impact in improving mathematics achievement, social and emotional competencies, computational thinking, and understanding of music notation among high-need kindergarten students. The evaluation will comprise two phases. The formative phase will augment Touro's development and continuous improvement of the YAM program. The summative phase will use a randomized control trial (RCT) study designed to meet What Works Clearinghouse standards without reservations to measure the implementation and impact of the YAM program on kindergarten students' two main outcomes from the confirmatory analysis, mathematical achievement and social and emotional competence, and two secondary outcomes from the exploratory analysis, computational thinking and music notation. The summative evaluation will further include an exploratory moderator analysis of these outcomes among students' demographic characteristics. These characteristics will include disability status, as a previous efficacy study of a music-based intervention for third grade mathematics reported strong effects for this particular subgroup (Courey, Balogh, Siker, & Paik, 2012).

Formative evaluation phase. During Years 1 and 2 of this early-phase grant, SRI will provide Touro with information to support the ongoing improvement of each component of the YAM program as it is piloted. The formative research will address teachers' perceptions of how well YAM helped students learn mathematics, computational thinking, and music, as well as teacher perceptions of the relevance, coherence, and feasibility of implementation of the curriculum and professional development supports. This information will be collected through

focus groups, interviews, and surveys of the pilot teacher participants, and will include their recommendations on how to maximize the engagement and participation of administrators, teachers, and students as the full intervention is implemented. In addition, SRI staff will collaborate with Touro in reviewing observation data from YAM classrooms in order to improve and refine YAM products. These formative data collection activities are aimed to support ongoing improvement of YAM, and also to allow SRI to develop and refine the implementation fidelity and quality measures and identify thresholds of these measures that will be incorporated into the summative evaluation.

Summative evaluation phase. To address the second goal of this project, during Years 3 and 4 of the project, SRI will employ a cluster randomized controlled trial, clustered at the teacher/classroom level and blocked by school, to test the impacts of YAM on student outcomes. The evaluation will be comprised of two cohorts of kindergarten students (Cohort 1 in the 2021-22 school year and Cohort 2 in the 2022-23 school year), resulting in a total of 1000 kindergarten students across 70 classrooms from approximately 15 schools in urban New York City school districts and urban and neighboring rural school districts in Austin, Texas (Please see school district demographic information in Appendix I). Cohort 1 will consist of 500 kindergarten students from 35 classrooms that will be randomly assigned to receive either the 18-session (9 week) intervention or conduct business-as-usual (BAU) mathematics instruction in spring 2022. Cohort 2 will consist of another 500 kindergarten students in classrooms randomized to either intervention or BAU comparison groups in spring 2023. Recognizing the critical importance of the districts' and schools' involvement and enthusiasm in the study, SRI will begin actively engaging with the districts during the first two years of the study, describing the project and the impact goals, explaining the purpose of an RCT design, and inviting districts to participate in the implementation and impact study.

Data collection includes measures of student demographic characteristics, student outcomes, and implementation fidelity. Findings on outcomes and implementation, and feedback on

progress toward intended outcomes will be shared through annual reports and regular project briefings.

Power Analysis

A previous efficacy study of a similar music-based mathematics instruction reported an effect size of 0.44 for the overall sample of students and 1.15 for a subsample of students who performed poorly at baseline (Courey et al., 2012). SRI conducted a power analysis estimating the minimum detectable effect size (MDES) for HLM analyses using the methodology in Schochet (2008). All calculations used the standard power level of .80 with a two-sided alpha of .05. The MDES is 0.231 for student outcomes, which falls below those found in the efficacy study. Thus, the proposed research design is well-powered for detecting treatment effects on student outcomes (see details of power analysis assumptions in Appendix I). Given that the proposed evaluation is based on a teacher-level RCT that is free of confounding factors and is expected to have low attrition, the summative evaluation is likely to produce strong evidence about the impact of YAM that will meet WWC evidence standards without reservations.

Evaluation Questions and Measures

Table 2 provides a list of the confirmatory and exploratory research questions that will be analyzed in the summative evaluation, including questions pertaining to implementation, mediator, and moderator analyses. Each research question is mapped to a specific outcome, along with the relevant data sources for each outcome. Details of each measure are described after the table.

Table 2. Evaluation Questions, Outcomes, Data Collection Tools and Measures

RQ	Outcomes	Data Collection Tools & Measures
RQ1 (Confirmatory). Do kindergarten students in the treatment classrooms show greater mathematics ability compared with students in the control classrooms?	Students' mathematics achievement	Pre-test: Mid-year district mathematics assessment obtained from student records Post-test: TEMA-3 (Ginsburg & Baroody, 2003)

RQ 2 (Confirmatory). Do kindergarten students in the treatment classrooms show greater social skills compared with students in the control classrooms?	Students' social and emotional competence	Pre- and post-test: DESSA (LeBuffe et al., 2009)
RQ 3-4 (Confirmatory, Implementation). To what extent is YAM implemented with fidelity? What are the factors that hinder or facilitate the implementation of YAM?	Implementation fidelity and quality	Observation protocols, teacher surveys, teacher interviews and focus groups
RQ 5 (Exploratory). Do students in the treatment classrooms show greater computational thinking skills compared with students in the control schools?	Students' computational thinking	Assessment developed and refined during development phase of project
RQ 6 (Exploratory). Do students in the treatment classrooms show greater understanding of music notation compared with students in the control classrooms?	Students' music notation understanding	Assessment developed and refined during development phase of project
RQ 7 (Moderator). To what extent is the impact of YAM on student outcomes moderated by **student** (e.g., student disability status and other demographic characteristics), **teacher/classroom** (teacher experience, probationary status, class size, and classroom average prior achievement), and **school** (school size, demographic composition, and district indicator) characteristics?	Test differential impact of YAM by student, teacher/class, and school characteristics in abovementioned student outcomes	Abovementioned student outcome and teacher/classroom, and school characteristics
RQ 8 (Mediator). To what extent is the impact of YAM on student outcomes mediated by the improved quality of teacher instructional practice?	Link Implementation fidelity and quality with student outcomes	Abovementioned implementation measures and student outcome measures in mediation analysis

Student outcome measures. To assess mathematics achievement, SRI will conduct direct assessments with students using the *Test of Early Mathematics Ability, third edition* (TEMA-3; Ginsburg & Baroody, 2003). TEMA-3 is a standardized, individually administered norm-reference test of mathematics performance for children ages 3 to 8. The 72-item assessment provides an overall score based on subscales measured for the following domains: numbering skills, number-comparison facility, numeral literacy, mastery of number facts, calculation skills, and understanding of concepts. TEMA-3 has been validated in numerous studies, with Cronbach's alpha above 0.92 (Ginsburg & Baroody, 2003: Hoffman & Grialou, 2005). TEMA-3

will be collected by SRI's external evaluation team at post-test in spring 2022 (Cohort 1) and spring 2023 (Cohort 2) following the 9-week intervention.

To explore the impact of YAM on social and emotional competence, the *Devereaux Student Strengths Assessment* (DESSA; LeBuffe, Shapiro, & Naglieri, 2009) will be administered. The DESSA is a norm-referenced behavior rating scale that assesses social and emotional competencies in students grades K-8. This teacher-reported measure consists of 72 items completed in 5-7 minutes that measure the following constructs: social-emotional competencies, cognitive competencies, interpersonal competencies, and intrapersonal competencies. The DESSA has been found to exhibit both convergent and divergent validity (Nickerson & Fishman, 2009) and shows a strong internal consistency of 0.90 (LeBuffe et al., 2014). The DESSA will be collected at pre-test in January/February just prior to the start of the YAM program implementation, and at post-test in April/May after the 9-week program is completed.

Assessments for computational thinking and comprehension of music notation have yet to be validated and demonstrated for widespread research purposes, particularly for early elementary students. As such, SRI will take an exploratory approach to the YAM program's effects on computational thinking and music by supporting the developers in co-constructing and piloting the assessment for its internal consistency during the first two years of the project.

Student background characteristics. SRI will collect demographics, special education status, free and reduced priced lunch status, and English Language Learner (ELL) status to use in the impact and moderation analyses. Mid-year district mathematics assessment scores also will be collected as a pre-test measure of academic achievement.

Data analysis plan

Main Impact Analysis. Given the clustered nature of the data, the magnitude of YAM program effects on student outcomes will be estimated using a Hierarchical Linear Modeling (HLM) strategy. HLM adjusts standard errors to account for the dependence among students within classrooms within schools, thereby avoiding the overestimation of statistical

significance of the effect size (Hedeker & Gibbons, 2006; Raudenbush & Bryk, 2002). To align with the random assignment procedures, treatment effects will be estimated at the class/teacher level. Additionally, classroom-, teacher-, school-, and when appropriate, student-level covariates will be included to reduce residual error and increase power. Spring post-test scores will serve as the dependent variable, while pretest scores will be included as a student-level covariate. Because two states/districts administer different math assessment for kindergartens at pretest, we will convert the pretest to z-score by the state or national mean and standard deviation for each state before we put them in the following HLM (May et al., 2009). Please refer to Appendix I, table I.1 for the HLM specifications.

Attrition. Though attrition at the school level is expected to be minimal and similar across conditions and student level attrition is expected to be around 15%, before conducting the impact analyses, SRI will monitor school and student overall and differential attrition rates throughout the course of the study and take corrective action to reduce it. Based on our prior experience with cluster RCTs, minimal teacher-level attrition and 15% student-level attrition is expected, qualifying this RCT study design to meet the WWC evidence standards without reservations.

Subgroup and moderation analysis. Reasonably-sized subgroups defined by student characteristics (e.g., special education, ELL, and ethnicity) will be tested to determine whether they benefit from YAM more than others. The HLM will be modified by adding the moderators as covariates and as grand-mean centered interactions with the treatment indicators. The coefficients of the interaction term will be tested using Wald's test to determine whether moderation effects are present.

Mediation. We hypothesize that staff reports of improved teacher instructional quality may mediate the effects of intervention on mathematics achievement and social emotional competence. SRI will use structural equation modeling to test mediation effects because of its superior ability to more properly address the presence of measurement error within a statistical model than regression models (Holbert & Stephenson, 2002; Iacobucci, Saldanha, & Deng, 2007; Little, Card, Bovaird, Preacher, & Crandall, 2007).

Implementation evaluation. During the Years 1 and 2 development phase of this study, SRI will analyze the multiple sources of implementation data sources to produce a matrix describing specific fidelity domains (e.g., professional development), indicators within each domain (e.g., teacher attendance, hours of participation), and critical thresholds for each implementation indicator and domain (e.g., 90% participation in full-day professional development trainings). This implementation matrix will then be used during the Years 3 and 4 efficacy study to supplement the impact analyses and provide guidance for how the YAM program might be implemented in other settings. Data sources for this implementation fidelity analysis will be derived from both qualitative and quantitative data. Teacher surveys will provide data on program uptake (intervention teachers only), the difference between the YAM program and the business as usual experience (intervention-comparison contrast) and perceived supports and barriers to implementing YAM. Analyses of these data will also examine similarities and differences across classrooms and schools to assess any variation in replication. Finally, data from teacher interviews will provide information on local conditions or contextual factors related to implementation, contamination, and cross-over (if the latter two occurred).

As part of the implementation evaluation, SRI will document the YAM program developers' work to provide guidance on effective strategies suitable for replication or testing across multiple contexts and with diverse populations. This will be done through artifact analysis (e.g., PD training agenda and materials), teacher and administrator interviews and surveys, observations of training, and site visits. SRI will study the resources the intervention developer allocated in developing teacher's capacity and experience with the supports, the teacher's developing expertise and sense of ownership of the YAM curriculum, and teachers' use of and experiences with YAM's curricular components across the different school sites. For each of these topics, we will pay close attention to local contextual factors that support or inhibit successful replication, documenting variation in implementation and adaptation to local needs. Final analysis will triangulate the local site contextual data with site-level implementation

fidelity and program uptake data and impact estimates with an eye towards identifying critical project components that can be replicated and sustained in various conditions.

Cost Effectiveness. For this early-phase study, SRI will determine a cost per student using the ingredients method (Levin & McEwan, 2001). Researchers will identify each program input through document review and implementation interviews, then identify and cost out a master list of program ingredients using data collected from sites, publicly available data, and the "Cost Out" tool (Hollands, et. al., 2015). SRI will then compare treatment to control ratios of program costs to benefits calculated.

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