INTRODUCTION

The New York Hall of Science (**NYSCI**)—along with the American Institutes for Research (**AIR**), the New York State Association for Computers and Technologies in Education (**NYSCATE**), and **10 implementation partners in New York State**—proposes a **mid-phase study**, to assess and built on the early successes of the **Playground Physics program**. The Playground Physics program consists of an iPad app, a middle school supplemental physics curriculum, and professional development (PD) for teachers. The program's **significant positive impact on student achievement** was demonstrated as part of an Investing in Innovation development (i3) grant (Friedman et al., 2017). The results of one **randomized controlled trial (RCT)** conducted with 45 teachers in New York City found that students whose teachers who were randomly assigned to implement Playground Physics had higher levels of physics knowledge than students whose teachers had been randomly assigned to a control condition. Sixty-four percent of students who participated in the study were from underrepresented groups or eligible for free or reduced-cost lunch (Friedman et al., 2017). This study **meets the "moderate evidence" standard** for this competition (see Appendix B).

Building on these positive results, the proposed mid-phase project will develop and implement a **train-the-trainers (TtT) strategy for scaling the Playground Physics program to 50 schools in NYS** that serve **high percentages of high-need students** (see Appendix G5), build **communities of practice (CoPs)** to support continued scaling, and test the effectiveness of the program to increase students' knowledge of, engagement with, interest in, and perceived utility of physics in **diverse settings**.

ABSOLUTE PRIORITIES ADDRESSED

The project addresses **Absolute Priority 1—Moderate Evidence—**by using Playground

Physics, which had statistically significant impact on high-need student achievement in physics—an area of **critical national need** (NSB, 2018; Metzer et al., 2012). The project also addresses **Absolute Priority 3—Promoting Science, Technology, Engineering, or Math (STEM) Education—**by offering engaging inquiry-based instructional physics materials and activities to general science teachers serving 6th, 7th, and 8th grade students. The teachers this program will engage are serving both high-need students and students from groups traditionally under-represented in STEM careers, another area of **critical national need** (USDE-OII, 2016).

A. SIGNIFICANCE

A.1. Severity of the Problem. This project addresses the science achievement gap for high-need students, who **are not being adequately prepared at the middle school level** to continue into advanced physics courses in high school. There is a major crisis in physics education at the high school level in the US (Meltzer & Otero, 2015) and particularly in New York State (NYEC, 2018). This problem stems in part from a lack of quality science experiences in earlier grades.

Overall, relatively few students take physics in high school. Only 63% of the nation's high school offer physics courses (USDE-OII, 2016). According to a recent nationally representative study of high school completers, while nearly all students (98%) took biology, and 76% took chemistry, only 41% took physics (NSB, 2018). Moreover, the relatively small group of physics-takers tends to be those of higher socioeconomic status (SES) (NAEP, 2015). This is consistent with a separate pattern of under-representation of students of color in AP STEM subjects. In particular, Black students constitute only 5% of students taking the AP Physics 1 exam. Furthermore, of those students who do take the test, only 14% of black test-takers and 19% of Hispanic test-takers average a 3 or higher, compared to 48% of white test-takers (NSB, 2018).

The **quality of science curricula** available to students in the **middle grade courses** plays a critical role in shaping the science course sequence accessible and appealing to youth as they reach high school. 90% of middle school students do not have adequate opportunities to learn physical science (PhysTEC, 2014). New York State Education Department's Core Science Curriculum for grades 5-8 shows a limited reference to physics topics and scientific inquiry through active laboratory work and hands-on activities. Despite the wide dissemination of the state's Core Curriculum, there is evidence that **access to physics education is not equitable**. **Black and Hispanic students in New York receive less physics instruction in 8th grade** than their peers**.** Over half of white 8th graders participated in science classes in which teachers reported spending "a lot" of time on physics. For black and Hispanic students, this figure was just over one-third (NAEP, 2015). **Science performance gaps** across racial/ethnic categories are also evident at the middle school level. In **New York** only 9% of black students and 13% of Hispanic students in 8th-grade science perform at or above proficiency, compared with 45% of white students (NAEP, 2015).

A.2. National Significance. Since **physics is a strong predictor of postsecondary STEM success** (Redmond-Sanogo, Angle, & Davis, 2016), the proposed project has the potential to improve STEM career pathways for **high-need middle school students**. The rigorous and engaging curriculum Playground Physics provides access to can prepare students for, and encourage their interest in, STEM study in high school (USDE-OII, 2016). By focusing on school districts serving **high percentages of high-need students**, the project will contribute to closing the achievement gap in science and STEM careers—an **area of critical national need**.

STEM jobs are increasingly prevalent in the U.S. economy and will continue to grow at a rate of 13% between 2017 and 2027 (ECS, 2018). While the number of STEM-educated workers are limited (ECS, 2018), the demand for high-level knowledgeable STEM workers has grown in many sectors of the U.S. economy: 80% of jobs created in the next decade will require STEM skills (NSF, 2015) and 20% will require a high level of knowledge in a STEM field (Rothwell, 2013). Blacks and Hispanics continue to be underrepresented in the STEM workforce, however: black workers represent 9% while Hispanics workers represent 7% (Funk & Parker, 2018).

This pattern of underrepresentation corresponds with the STEM opportunity gaps that persist throughout the K-12 education system across racial, socio-economic, gender, and geographic lines (Sass, 2015; USDE-OII, 2016). The system is struggling to provide low-performing students with adequate core STEM content and important cognitive knowledge and skills (Rothwell, 2013). Low science achievement and limited science understanding widen social stratification and lead to employment barriers for high-need students.

Although middle school years are a formative period for cognitive and social development, especially with regard to future engagement with STEM fields (Kuhn, 2009; Sass, 2015), **apathy**, **lack of motivation, and disengagement are challenges to teaching youth in middle school** (Quinn & Cooc, 2015; Wang & Holcombe, 2010), especially in science classes (Lyon et al., 2012). When students become disengaged during the middle school years, it becomes difficult to engage in advanced STEM studies in high school and pursue STEM careers.

Altering the STEM learning trajectory for these students requires access to both **effective and engaging curricular resources** and **adequate training and support for science teachers** (USDE-OII, 2016). Playground Physics is designed to address this area of critical national need by offering instructional materials and pedagogical support to general middle school science teachers to support and empower them in fostering students' engagement with and knowledge of physics. The **compelling and playful inquiry-based science** approach of Playground Physics enables teachers to improve their student achievement in science (Harris et al., 2014). As noted, this program has proven to be associated with greater levels of student knowledge of middle school physics concepts (Friedman et al., 2017).

A.3. Exceptional Approach to Absolute Priorities 1 and 3. This project represents an exceptional approach to Absolute Priority 1—**Moderate Evidence**—because of the **proven positive impact of Playground Physics** on a sample of more than 1,000 students, 64% of whom were from underrepresented groups or eligible for free or reduced-cost lunch.

Playground Physics' exceptional approach to Absolute Priority 3—**Promoting STEM Education**—is evidenced by a successful **integration of playful informal science learning and formal teaching** to support **high-need students' learning of complex physics concepts**. Playground Physics is infused with the sensibilities of informal science learning environments: it offers multiple playful ways (physically, emotionally, and cognitively) to explore physics content; presents multifaceted and dynamic portrayals of physics data; and supports learner-driven interactions with phenomena (Honey & Kanter, 2013; USDE-OII, 2016). Informal learning environments give learners the opportunity to actively shape the tasks they are working on, while interacting with skilled facilitators who ask relevant questions and provide guidance, an approach which has been shown to enrich learning (Robertson et al., 2015). This approach has a positive impact on students' science affect, including motivation and engagement (USDE-OII, 2016). Blending physical play and virtual activities to support rigorous physics learning, Playground Physics creates such an environment, allowing students to see a visual link between their play performance videos and graphed data of those performances (see Appendix G4).

With the adoption of the Next Generation Science standards (NGSS) in many states (NGSS Lead States, 2013) and the newly revised New York State Science Learning Standards

(NYSSLS) (NYSED, 2017), **educators are in need of three-dimensional** (i.e., incorporating science practices, disciplinary core ideas, and crosscutting concepts) **instructional materials** that authentically engage students with science and engineering practices, disciplinary core ideas, and crosscutting concepts. Inherently three dimensional, the Playground Physics curriculum is exceptionally well-suited to addressing the NGSS Middle School Performance Expectations related to Forces and Interactions, including "Applying Newtown's Third Law to design a solution to a problem involving the motion of two colliding objects" and "Planning and conducting an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object."

Playground Physics App: The centerpiece of the program is an **iOS app for iPads** that enable learners to visualize and reflect on scientific data to deepen their learning of three physics concepts: energy, force, and motion. Students use the app to record a video of an action (e.g., swinging, running) or can choose a stock video. This video becomes a subject for students' investigations. In the "motion" lens, students connect the performance with variables like distance, speed, and direction change. In the "force" lens, students identify force pairs (i.e., pull, push) at work in the action. In the "energy" lens, students explore a person or object's potential and kinetic energy. Using these lenses, Playground Physics connects complex physics concepts students learn about in school to actions they perform in their daily lives, and helps them identify how physics can be used to explain their own experiences of the world.

The app supports students' exploration of interactive graphs, allowing them to trace a path of motion by tapping points along the video, enter known measurements (i.e., height, mass), and add stickers to mark important play moments. Graphs display the distance traveled and speed along the path and in horizontal and vertical vectors (see Appendix G4). These features support guided inquiry (Harris et al., 2014) and encourage students to explore the relationship between actions in the video and core physics concepts. The app is designed to scaffold students toward higher-order thinking and the discovery of new patterns and new questions (Csikszenymihalyi, 1996; Sternberg & Lubart, 1999).

Playground Physics Curriculum: The Playground Physics curriculum is a middle school supplemental six-week physics curriculum, designed to be used alongside any existing science curricula. It is contained in a teacher's guide and a student workbook and maps to the NGSS and NYSSLS. The introductory lesson familiarizes students with the functions of the app. The initial lesson in each unit employs a series of questions to guide teachers in assessing students' prior content knowledge. Subsequent lessons build on one another to actively engage students through the use of the app and unit activities. Students are encouraged to engage in conversations prompted by questions that come up while exploring their video performances and associated graphs. For example, why does the graph of speed for a jump go down when the person is at the highest point off the ground? Students end each sequence reflecting on what they learned and how and why their ideas might have changed.

Playground Physics PD: Informed by the Scale Immersion Model for Professional Learning (SIMPL) (Weiss et al., 2010), the Playground Physics PD is a multistep, iterative learning process in which teachers first experience the content as learners (Mundry & Stiles, 2009). In playful and rigorous inquiry-based workshops (Gunckel, 2011), teachers learn how to use the app and explore physics topics through hands-on activities embedded in each lesson. Then, they reflect on how to realistically implement the curriculum in their classrooms by linking students' physical experiences of play to the core physics concepts of energy, force, and motion.

In sum, **Playground Physics uses an approach backed by evidence and theory**. We propose to extend that base of evidence, examining the implementation and impact of Playground Physics when delivered using the scaling strategy described in Section B.

B. STRATEGY TO SCALE-UP

B.1. Unmet Demand. Scalable, effective, and engaging inquiry-based science programs with well-integrated pedagogical support mechanisms for middle school teachers are in **demand**, especially in schools serving large populations of **high-need students** (LCEF, 2015; USDE-OII, 2016). When the research and development of Playground Physics started six years ago, it was in response to national calls to leverage advanced technologies to bridge formal and informal science learning and to boost high-need middle school students' passion for science by deepening their learning through experimentation and inquiry (PCAST, 2010). Widespread **demand** for the program remains: more than **1,300** people from the U.S. have visited the Playground Physics webpage on NYSCI's website in the past year, with 77% being new users, and **400,272** copies of the app have been downloaded in the U.S. and Canada.

The lack of access to suitable science curricula is a persistent problem for high-need schools in New York State (NYEC, 2018). In a study of 33 high-need schools in the state, 13 reported "they were not providing students with sufficient instruction to meet the state's minimum curricular requirements in science" (CEE, 2012, p. 3). Seventy percent of 8th graders in New York State were performing below the NAEP proficient level in 2015 (NCES, 2018). **Demand for scaling the Playground Physics program in New York State** is also evidenced by requests from our partners in this project, including New York State Commissioner of Education, Executive Director of STEM for the New York City Department of Education, Executive Director of NYSCATE, Executive Director of the Capital Area School Development

Association, and district and school leaders across the state (see Appendix C). These demands demonstrate the need for an effective and engaging inquiry-based science program that can supplement current offerings for high-need middle school students (see Appendix G5)—for which Playground Physics is uniquely suited.

B2. Specific Strategies to Achieving Proposed Level of Scale. A rigorous study of Playground Physics' impact on high-need middle school students has been limited to New York City (Friedman et al., 2017). Scaling-up the program to 50 schools across New York State will require **broadening access to the app** to 9,800 students, and **developing a sustainable, high-quality and cost-effective PD strategy for training** 100 teachers. To scale and test the program in **a variety of settings and with a variety of populations**, we plan to use a **train-the-trainer strategy** with a blended (both face-to-face and online) and multilayered infrastructure. This approach is designed to create communities of practice for both trainers and teachers, draw on the NYSCATE support system to deliver the Playground Physics' PD, and test the potential for scaling the program nationally by International Society for Technology in Education (ISTE) affiliated organizations, like NYSCATE, present in all 50 states. Additionally, NYSCI will make the program compatible to the most commonly used current technology platforms and utilize a statewide network for PD and ongoing support.

App Access Issues and Solutions. The Playground Physics **iPad app**'s recording, playback, annotation, and visualization of videos and associated data are key components of the learning process. These functions are designed to support students in observing and noticing with the goal of building their understanding of core physics concepts. The app was built in 2012 for iPads; at the time, the iOS platform and iPad best afforded recording, annotating, and analyzing video in a single, high-performance device. Since then, Chromebooks have come to dominate the school market for devices. Chromebooks made up 58% of the United States K-12 school market, while iPads had only 14% (Futuresource Consulting, 2017).

To address the access issue caused by these changes, we will develop a **web-based version of the Playground Physics app that can be used on laptops and Chromebooks**. The web-based app will allow students to record videos on any device (e.g., digital camera, smartphone), upload the videos to the Playground Physics app, and analyze their videos from their Chromebooks or laptops. This web version will expand the program by making it available to all students who have access to a computer and the internet.

Scaling and Sustaining Playground Physics PD across New York State. To address the barrier to scaling the PD program, NYSCI and NYSCATE will develop a **train-the-trainer program**, which is an effective and low-cost method for promoting educational change on a large-scale, organizational level (Pollnow, 2012).

Despite the effectiveness of this model, it has its limitations, particularly in fidelity and follow-through at trainers' implementation sites (Campbell et al., 2005). A proven way to overcome this barrier is to embed the TtT program with **support** that **is continuous**, **job-embedded**, **data driven**, and targeted to the **specific needs of students and staff** (Weiner & Pimentel, 2017). When combined with support (e.g., in-person and online meetings, classroom observations) and feedback, the transfer of knowledge and skills into the classroom practice increases to 80-95%, compared with 5-10 % with a standard TtT experience (Pollnow & Tkatchov, 2012).

With this in mind, we will create **a blended TtT model that combines face-to-face trainings, an online coaching and support system, and the cultivation of an ongoing CoP** for both trainers and teachers. CoPs are organized around their members' shared learning and interests, and develop through regular interactions (Wenger-Trayner & Wenger-Trayner, 2015; Barab et al., 2001). With this approach, coaches and teachers are not just implementing a set of lessons but are being invited to think critically about how to best leverage Playground Physics to support high-need students learning—making it more likely to motivate them to continue using the program and other inquiry-based instructional materials (Marzano & Simms, 2013).

This integrated face-to-face and online model of support is designed to deliver the program to **one program manager (PM) and eight coaches** from NYSCATE, and **100 teachers** in New York State. This strategy to scale and provide ongoing support requires NYSCI to develop a TtT program and materials aligned with NYSCATE's existing models for PD and coaching, and train **the PM and eight coaches**. In turn, these coaches will deliver the PD workshops to participating teachers from the same districts, who can then implement the program in their classrooms (see C2 for details about roles and responsibilities of NYSCI, NYSCATE, and teachers).

Develop TtT program and materials. **NYSCI will develop TtT program and materials** to provide scaffolds and support for participating coaches. These materials will include videos; a coaching guide containing training facilitation materials, observation guides, and probing questions; and an online platform for coaches' and teachers' discussions and check-in meetings. The PM will provide feedback on TtT program development to ensure alignment with NYSCATE's goals and practices, and support the delivery of TtT program to coaches.

Train PM and Coaches. **NYSCI trainers will conduct the three-day in-person training for the PM and eight coaches**. The PM will participate in the training of the coaches to get familiar with the training; this will give them the ability to support potential delivery of the training in future years as a sustainability mechanism. The coaches' training activities will include developing a deep understanding of (1) the Playground Physics' learner-centered, playful, active-learning approach to physics, (2) the SIMPL model of PD in which teachers first experience the content as learners (Mundry & Stiles, 2009), and (3) observation and recording techniques that are key to building strong CoPs (Weiner & Pimental, 2017).

During the training, coaches will experience and learn how to lead teachers through inquiry-based activities—as they actively explore physics content. They will also practice observing and recording learners' ideas about the use of Playground Physics, and use these observations to guide instructional conversations and identify shared problems of practice. The sharing of experiences and observations, and the resulting instructional conversations, will provide opportunities to collaborate and share expertise, not just increase content knowledge. Coaches will also be introduced to and begin working in the online space used to further the post-training.

By the end of their training, coaches will have a detailed agenda and curriculum for leading the identified schools and teachers in their PD. Coaches will be able to effectively use the app and curriculum in the context of classroom activities, know how to facilitate rich discussion and sustained exploration of the app by students and teachers, understand how the curriculum is aligned to state and NGSS standards, begin to participate in a CoP, and feel prepared to deliver training and support to participating teachers.

Support Coaches. After the training, **NYSCI staff and the PM will use the online platform to continue to support the CoP for trained coaches**. The focus of the CoP is increasing the coaches' effectiveness in relation to the type of learning that Playground Physics embodies. The online platform is a space for the PM and coaches to receive ongoing support, solve challenges, and reflect on what they are learning in their work with the teachers.

NYSCI staff will develop weekly online prompts or share resources to foster discussion among coaches. Prompts could be as simple as "Everyone share one success and one challenge from your work this week" or as in-depth as coaches submitting a problem of practice which the collective group can analyze and address. Weekly deadlines help sustain engagement and create community over time. The coaches will also be encouraged to raise their own topics for discussion, share additional resources, or highlight areas where they feel they need further support. All coaches and the PM will have a virtual check in (videoconference) with NYSCI staff right after they train teachers, to identify problems, successes, and next steps in supporting the teachers. Once teachers have wrapped up implementation, the coaches will hold a culminating videoconference to reflect on their growth as coaches and to think about how they might provide this training again the following year.

Train Teachers. The **coaches will deliver a blended PD model** comprising an in-person workshop and online discussion platform. The workshop will prepare teachers in implementing the program in their classrooms and the discussion platform will support teachers in forming their own CoPs to ensure that they get needed support as implementation questions arise.

Teachers will participate in a **two-day in-person workshop** in which teachers experience the content as learners and engage in inquiry of science concepts (Mundry & Stiles, 2009). The workshop will begin by engaging and eliciting teachers' ideas about pedagogy, use of technology in the classroom, and ideas about how science and play connect. Teachers will then have an opportunity to work with the app, explain and reflect on what they learned, and revisit their initial conceptions in order to be metacognitive about their learning (Mundry & Stiles, 2009). Teachers from the same districts will work together to develop a plan to integrate Playground Physics into their existing science curricular materials, and indicate when they will teach each unit. They will implement the program in their classrooms in the fall of 2019 (Cohort 1), spring of 2020 (Cohort 2), fall of 2020 (Cohort 3), and fall 2021 (Cohort 4) (see C2 for more implementation details).

Support Teachers. Teachers will work with their assigned coach in an **online CoP space** to engage in activities that promote ongoing collaboration and dialogue, and to work through questions that require additional support (e.g., how to use data generated from the app to inform other instructional decisions). Coaches' weekly posts in the online discussion forum will reinforce teachers' learning at the in-person PD workshop. The CoP space will be structured less for the coach to answer questions and share resources, and more for the teachers to share work and reflect on it as they implement their units. This will ensure that coaches and teachers see the online forum as an integral part of their experience, rather as an add-on. Teachers may request face-to-face check-in meetings with coaches as needed.

B.3. Feasibility of Successful Replication in a Variety of Settings and Populations. Ownership and PD capacity building are two critical factors in "adapting a locally successful innovation to a wide variety of settings while retaining its effectiveness" (Dede et al., 2005, p. xiii). If the scaled Playground Physics program is proven to have positive impact on students' knowledge of, engagement with, interest in, and perceived utility of physics, it will be **feasible** for NYSCATE to incorporate it into its PD offerings for middle school science teachers across the state. To make **replication feasible**, the PM will create sustainability plan for NYSCATE to integrate into future offerings. NYSCATE and participating school districts recognize the potential large-scale benefits of the program (see Appendix C) and will lead the Playground Physics TtT model and build the capacity of district-level staff developers through that training. The project will make available the training materials to NYSCATE, including the Playground Physics **app** (accessible on iPads, laptops, and tablets**)**, **curriculum**, **coach guide** for implementing the TtT and CoP strategies and tools, and **lessons learned** from the implementation. The resources will be made available on the NYSCI's and NYSCATE's website. Further, the PM will create a sustainability plan for dissemination of the model to ISTE affiliated organizations present in each state.

C. QUALITY OF THE PROJECT DESIGN AND MANAGEMENT PLAN

C.1. Clearly Specified and Measurable Objectives, Outcomes, and Indicators. The goal of this project is to test and refine a strategy for scaling and sustaining Playground Physics in diverse middle school settings and for diverse populations in New York State. Table 1 presents the program's objectives and strategies to be developed and implemented, the outcomes and indicators to be achieved, and how we will measure each of those objectives.

Table 1: Summary of Project Objectives, Strategies, Outcomes, Indicators, and Measures

Strategies	Outcomes	Indicators of Success	Measures
Objective 1. Implement strategy to scale with fidelity and continuous improvement			
Strategy 1.1. Create a web-based app of Playground Physics	Outcome 1.1. Broaden access to the Playground Physics app	Indicator 1.1.a. On-time completion of app; Indicator 1.1.b. Level of website usage	Monthly reports from web-developer; Website usage data
Strategy 1.2. Develop videos for coaches, coach guide, and online forum for coaches and teachers	Outcome 1.2. Deliver videos, coach guide, and fully functioning online tools	Indicator 1.2. On-time completion and distribution of videos, guide, and forum	Program records documenting; completion and distribution
Strategy 1.3. Identify eight (8) NYSCATE coaches	Outcome 1.3. Describe criteria: commitment, sufficient qualifications and skills, etc.	Indicator 1.3.a. Existence of criteria and their application in coach selection Indicator 1.3.b. On-time selection of eight coaches	Program records documenting criteria; Program records documenting selection
Strategy 1.4. Train PM and coaches	Outcome 1.4. Fully trained PM and coaches	Indicator 1.4 Coach ratings of workshop effectiveness	Post-TtT training surveys; Extant data from coach CoP
Strategy 1.5. Train teachers	Outcome 1.5. Fully trained teachers	Indicator 1.5.a. Teacher ratings of PD effectiveness; Indicator 1.5.b. Teacher participation in PD	Post-PD surveys; Attendance records from PD

Strategy 1.6. Refine materials and procedures for each strategy under Objective 1	Outcome 1.6. Improved curriculum, web-based app, videos, guide, and chat room	Indicator 1.6. On-time revisions of resources; Changes in web-app usage	Program records documenting revisions; website usage data
Objective 2. Implement Playground Physics in classrooms with fidelity, ongoing support, and continuous improvement			
Strategy 2.1. Cultivate the online CoP for coaches	Outcome 2.1 Coaches participate in online community via posts and content sharing	Indicator 2.1 Participate in check-in meetings; Indicator 2.1.b. Coach participation in online CoP	Extant data from online coach CoP
Strategy 2.2. Support coaches in cultivating the online CoP for teachers	Outcome 2.2. Coaches deploy effective strategies for cultivating teacher participation	Indicator 2.2. Coaches initiate weekly discussions	Extant data on coaching strategies used in online teacher CoP
Strategy 2.3 Implement all three curriculum units	Outcome 2.3. Trained teachers implement curricular activities with fidelity	Indicator 2.3. Number of units/lessons implemented	Teacher survey
Strategy 2.4. Support teachers via a CoP	Outcome 2.4 Participate in online community via readings, posts, and content sharing	Indicator 2.4.a. Teacher participation in check-in meetings; Indicator 2.1.b. Teacher participation in online CoP	Extant data from online teacher community on participation
Strategy 2.5. Monitor and refine activities under Objective 2	Outcome 2.5.a. Improved implementation of curriculum at the classroom level; Outcome 2.5.b. All coaches and teachers fully participated in CoP activities	Indicator 2.5.a,b. Increase across teacher cohorts in curriculum implementation and participation in CoP	Extant data from teacher and coach online CoP; Teacher survey
Objective 3. Test the effectiveness of the scaled program to increase students' physics knowledge, engagement in physics lessons, and physics-related attitudes as measured			
Strategy 3.1. Develop and evaluate outcome measures	Outcome 3.1. All outcome measures are valid and reliable	Indicator 3.1. Rasch statistics indicate strong fit; reliability exceeds 0.70	Output from Rasch analyses
Strategy 3.2. Design and execute impact study with rigor	Outcome 3.2. Study completed as intended	Indicator 3.2. Study meets WWC standards without reservations	Feedback from EIR evaluation technical assistance provider
Objective 4. Integrate to NYSCATE PD offerings for continued scaling of Playground Physics			
Strategy 4.1. Continue to support the work of the coach and teacher CoPs	Outcome 4.1. Playground Physics' communities of practice network that support coaches and teachers	Indicator 4.1. Teacher and coach online CoPs maintain or increase vitality	Extant data on level of participation in online CoPs

Strategy 4.2. Recruit additional districts	Outcome 4.1. Commitment of districts to continue to participate in project	Indicator 4.2.a. Percentage of districts continuing participation; Indicators 4.2.b. Number of new districts	Program records documenting district commitments to participate
Strategy 4.3. Create sustainability plan to integrate program into future offerings in New York State and to share program with other ISTE affiliated organizations	Outcome 4.3. Tools and procedures for implementing Playground Physics as part of a coherent system of teacher support	Indicator 4.3 Completion of sustainability plan and of tools and procedures.	Program records documenting completion of plan, tools, and procedures

C.2. Management Plan: Responsibilities, Timelines, and Milestones. The project team has articulated a **four-year management-plan** with tasks, timelines, and milestones (see detailed management plan in Appendix G1) to address the project's **four objectives**.

Management Team Responsibilities and Expertise. To successfully implement the project, **NYSCI—the lead organization for the project**—has assembled a team of researchers, professional developers, and advisers with expertise about science education and deep knowledge of New York State education leadership structure and systems of support, geographically diverse school settings, and groups underrepresented in STEM. NYSCI will provide overall leadership and oversight of all program activities, including developing TtT and CoP models, and maintaining communications and relationships with partners. ***NYSCI Lead Staff***: Harouna Ba, project director; Katherine Culp, co-project director; Margaret Honey, senior advisor; and Michaela Labriole, program coordinator (see Appendix B for resumes).

NYSCI is one of the nation's leading science and technology centers, offering STEM education through informal, hands-on learning products and services to **300,000 K-12 students per year**, and highly effective professional development to approximately **2,000 teachers each year**. These PD offerings range from half-day workshops to intensive coaching and extended institutes. In all of its PD programs, NYSCI engages teachers as professionals in learning, reflection, and dialogue; enables them to acquire STEM content and skills that are closely aligned with classroom practice and education frameworks; and provides resources that have been proven to work in classroom settings. According to independent evaluations, NYSCI's PD programs have been repeatedly shown to increase teacher content knowledge in the sciences and to promote use of the most current science education pedagogy.

NYSCATE will lead the scaling-up of the PD model in New York State. Working with the districts, NYSCATE will oversee the eight coaches, provide ongoing support to the coaches and teachers to ensure the fidelity of implementation, and create a sustainability plan for the ongoing dissemination and use of the program in New York State and with ISTE affiliated organization across the country. ***NYSCATE Lead Staff***: Amy Perry-DelCorvo, statewide advisor; Carmalita Seitz, project manager (see Appendix B for resumes).

NYSCATE is a non-profit education technology organization representing more than **30,000 educators and administrators in New York State**. NYSCATE's partners include the New York State Education Department, school districts and Regional Information Centers, private corporations, and local and national educational organizations such as ISTE. NYSCATE also contributes to state policies regarding using technology in specific content areas like science in education (NYSCATE, 2017).

AIR will lead the independent evaluation. AIR's work will oversee the study design and execution, monitor quality assurance, and provide methodological direction. ***AIR Lead Staff***: Lawrence Friedman, co-project director; Jonathan Margolin, co-project director; Andrew Swanlund, analytic lead; Jingtong Pan, evaluation coordinator (see Appendix B for resumes).

AIR has 65 years of experience in evaluating education implementations of local and state education agencies, the U.S. Department of Education, and private sector nonprofit and for-profit entities. NYSCI and AIR's past partnership on an i3 development study (2012-2017) yielded a rigorous study of Playground Physics' impact (Friedman et al., 2017).

Management Team Interactions. The team leadership (project director, co-directors, project coordinator and manager, advisors) will hold **monthly meetings** to review the plan, monitor progress, and recommend direction and any necessary adjustments. They will ensure the project's research agenda is conducted effectively and in alignment with project goals and objectives, and confirm that the sustainability plans are put in place.

The project director, project coordinator and manager, and respective project staff will meet **bi-weekly** to review and discuss key implementation components, including recruitment of schools and teachers, product development, training of coaches and teachers, online PD support, evaluation studies, and dissemination. The evaluation team will join these check-in meetings on an as-needed basis. This process will afford rapid responses to implementation challenges and generation of agreed-upon solutions.

The project coordinator and manager and project staff will hold **weekly meetings** to cover every aspect of the project with special focus on training and supporting coaches and teachers, cultivating the online discussion forums. This team will work closely with district and school administrators, and participating teachers to address their implementation concerns and ensure successful implementation of project components in each district and school.

An **interdisciplinary team of advisors** will strengthen the work of the project team. The advisors include Ellen Meier, **director of the Center for Technology and School Change at Columbia Teachers College**; David Little, **executive director of the Rural Schools Association of New York**; Pamela Buffington, **co-director of Science and Mathematics Programs at Education Development Center**, and Mary Murphy, **associate professor and**

expert in STEM learning in the Department of Psychological Sciences at Indiana University (see Appendix B for resumes). The advisors will meet with project staff five times throughout the project to assist with planning and mid-course modifications.

Timeline. The project timeline is organized into two phases: launch and implementation in Years 1 and 2, and evaluation and dissemination in Years 2, 3, and 4.

Phase I: Launch and Implementation (Fall 2018 - Summer 2020): In Year 1, we will revise and pilot test research instruments, and develop and test the TtT model and materials. Once the TtT program and web-based app are created in Year 1, we will train the PM and select eight coaches who have experience serving schools with a wide range of locations and student populations in the winter and spring of 2019. The coaches will then lead PD workshops and CoP activities for teachers in summer 2019 and winter 2020 (Cohorts 1-2).

After the trainings and before implementing the program in their classrooms, teachers will have access to online videos they can use to review the PD activities, and an online platform where they can engage in dialogue with colleagues, coaches, and NYSCI staff in ways that will support their implementation. Teachers within each school will coordinate with each other to facilitate use of materials and technology as needed.

In Year 2, the first cohort of 10 teachers (from approximately five schools) trained in the summer of 2019 will implement the program in their classrooms in the fall of 2019. The second cohort of 10 teachers (from another five schools) trained in the winter of 2020 will implement the program in their classrooms in the spring of 2020. The timing of the two implementations will allow us to evaluate the effectiveness of the TtT and CoP model and make needed improvements (see C3 about continuous improvement below).

Phase II: Evaluation and Dissemination (Summer 2020 - September 2022): In Years 2, 3, and 4, we will conduct an randomize controlled trial (RCT) to test the impact of the PD, delivered through the TtT and CoP model, on students' knowledge of, engagement with, interest in, and perceived utility of physics; and make final improvement to the program. Forty schools, 80 teachers and 7,840 students will participate in this RCT, with one teacher per school randomly assigned to receive training summer 2020 and implementing the program in their classrooms in the 2020-21 school year, and one teacher per school assigned to a delayed-treatment control condition.

In Years 3 and 4, the teachers from the delayed-treatment control group will receive the PD (as cohort 4) in summer 2021 and participate in further testing of the scale-up model as they implement the program in the 2021-22 school year. We will disseminate the RCT findings and make final improvement to the TtT and CoP model. We will create sustainability plan for state and nationwide dissemination of the program.

C.3. Feedback and Continuous Improvement Procedures.

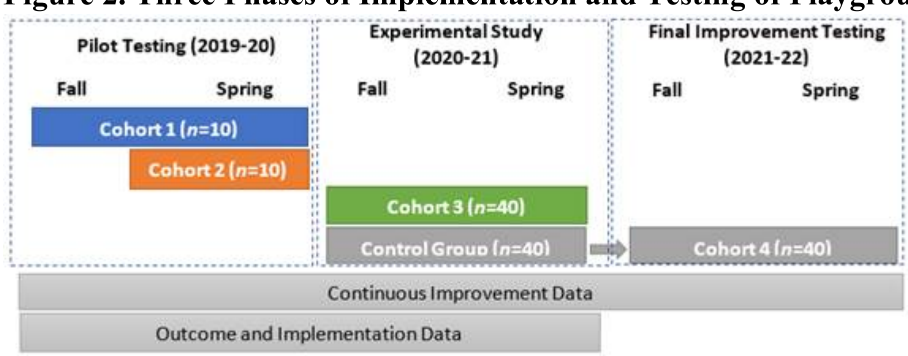
AIR will support the project team with a structured process for continuous improvement of the coach training and teacher PD workshops, as well as the CoPs for coaches and teachers. The continuous improvement process will include both a detailed plan to document the success and challenges of the project and feedback loops to make improvements.

Continuous Improvement Data. Data collection for continuous improvement will include four data sources, collected for all cohorts: 1) Post-workshop surveys will assess the quality and effectiveness of both the TtT and PD workshops; 2) attendance logs for face-to-face workshops will quantify level of participation; 3) extant data from online CoPs (of both coaches and teachers) will quantify both the level of participation and, in the case of the teacher CoPs, the number and type of coaching strategies used by coaches; and 4) data collected via a teacher survey (see Appendix G3 for more details) will indicate fidelity of classroom implementation.

Feedback Loops. Findings from these data will be reported to the project team at four points, namely, following the PD and coaching delivered to each teacher cohort, permitting time to revise the components of the TtT model for each subsequent cohort. These continuous improvement reports will provide feedback that compares current implementation to the indicators for success and criteria for fidelity, thereby highlighting successes and challenges. AIR will also provide feedback on the implementation of project objectives (see Table 1) to the project team, drawing on the data sources listed above as well as program artifacts (e.g., development of products) and records (e.g., dates of product completion, district participation). To this end, AIR will conduct an annual interview with the NYSCI project director to compare the year's actual and planned activities and identify reasons for differences.

Three phases of continuous improvement. We propose a three-phase approach to continuous improvement (see Figure 2). Although data will be collected from all teacher cohorts, we propose an in-depth continuous improvement process during the Pilot Phase with Cohorts 1 and 2. This early focus on continuous improvement will allow for revisions to the components of the TtT approach to inform the experimental trial (Cohort 3). Based on the experimental trial, we also will continue to refine the TtT model with Cohort 4 in their final year of implementation.

Figure 2. Three Phases of Implementation and Testing of Playground Physics



n = number of teachers.
Note: Schools in the Control Group in 2020-21 receive the program as Cohort 4 in 2021-22.

C.4. Sustainability. During the i3 development study, **3,128** NYC Department of Education students took part in *Playground Physics* activities. In collaboration with **NYSCATE** and 10 implementation partners, we **plan to expand** these offerings to **9,800** students in 50 **rural, suburban, and urban** schools in New York State during this mid-phase study.

NYSCI's **partnership with NYSCATE is a key strategic** element of this proposal, because of NYSCATE's extensive PD work with school districts and professional support networks across New York State. NYSCATE has an established track record and relationships, and deep expertise in providing training about best practices and technologies for improving science learning of high-need students. We will scale the use of Playground Physics in New York State by leveraging NYSCATE's statewide system of PD support both for the purposes of this mid-phase study, and **for the long term**. Beyond the life of the proposed project, NYSCATE has agreed to **integrate Playground Physics into its PD offerings** if proven to be effective in increasing the physics achievement of students in New York. As we also look forward toward national scale-up of this intervention, NYSCATE has also agreed to assist in **developing statewide strategies** for PD and dissemination through other ISTE-affiliated organizations, which are present in all 50 states (see www.iste.org). The scale-up model for this mid-phase study is designed to align with the goals and practices of this national network of state-level supports for K-12 education, which makes Playground Physics well-positioned for national dissemination and support.

D. PROJECT EVALUATION

With this grant, NYSCI will test its successful Playground Physics supplementary curriculum in classrooms of middle school science teachers in 40 schools across New York State and establish whether the intervention would be similarly successful using a train-the-trainer (TtT) approach to professional development and ongoing support (via an online CoP). The research questions (RQs) listed in Table 2 address student outcomes, teacher outcomes, and fidelity of implementation of the scale-up model and the Playground Physics program.

Table 2. Research Questions

Impacts on Student Outcomes	
RQ1	What is the impact of the Playground Physics curriculum on middle school students' knowledge of, engagement with, interest in, and perceived utility of physics?
RQ2	What is the impact of the Playground Physics curriculum on middle school students' engagement with physics content and attitudes towards physics?
Implementation Fidelity	
RQ3	To what extent were the TtT sessions and follow-up support provided to NYSCATE trainers?
RQ4	To what extent do NYSCATE trainers provide the Playground Physics professional development and support model to teachers as designed?
RQ5	To what extent do teachers participate in the professional development and support program?
RQ6	To what extent do teachers implement Playground Physics in the classroom?
Implementation Fidelity, Teacher Outcomes, and Student Outcomes	
RQ7	What is the relationship between teachers' participation in the Playground Physics professional development and support program and teachers' implementation of Playground Physics?
RQ8	What is the relationship between teachers' participation in the Playground Physics professional development and support program and teachers' use of inquiry-oriented instruction to teach physics concepts?
RQ9	What is the relationship between the extent to which teachers implement Playground Physics curriculum and middle school students' knowledge and understanding of physics concepts of motion, force, and energy?
RQ10	What is the relationship between the extent to which teachers implement Playground Physics curriculum and students' engagement, interest in, and perceived utility of physics?

D.1. Well-Designed Experimental Study. We will conduct a blocked cluster-randomized experimental study with teacher-level random assignment within schools to test the effectiveness of the Playground Physics program delivered by teachers trained through a TtT model by a network of trainers affiliated with NYSCATE. This study will examine the implementation and impact of the TtT model of Playground Physics in 40 schools across New York state using a design that will meet What Works Clearinghouse standards without reservations. We propose a multisite, cluster-randomized experiment where students are nested within teachers which are randomized within sites (schools) to Playground Physics or delayed-treatment control. Random assignment of teachers will be blocked by school to control for between-school variations in student demographics, teacher characteristics, and school administration.

As described, this study comprises four cohorts of teachers (see Figure 2). Cohorts 1 and 2 will participate in pilot testing of implementation and outcomes measures, and Cohorts 3 and 4 will participate in an experimental study as the treatment and delayed-treatment control teachers, respectively. Teachers assigned to treatment (Cohort 3) will receive Playground Physics professional development, support, and materials and implement the program in 2020-21. Cohort 4, the delayed-treatment teachers, will provide business-as-usual physics instruction in 2020-21, and then receive the program and participate in final improvement testing in the following year. We will compare the outcomes between Cohort 3 and Cohort 4 at the end of the 2020-21 school year to test if the TtT model of Playground Physics has a positive impact on student outcomes.

Sample. The analysis sample for the impact study includes 40 schools, 80 teachers, and 7,840 middle school students in grades 6, 7, or 8 taught by Playground Physics or control teachers during 2020-21. AIR will develop and execute the strategy to recruit teachers, schools, and districts working with NYSCI, NYSCATE, and 10 implementation partners. Two middle schools and eight districts (including Yonkers Public Schools with 30 middle schools) have already agreed to participate (see Letters of Support in Appendix C). We will recruit a sample of 40 middle schools that is representative of New York's middle schools with respect to their locales and regions, which will enhance the external validity of the study, and to the extent New York middle schools are similar to non-New York middle schools, enhance the external validity of the study further. We will use a strategic sample selection plan (Tipton & Peck, 2016) to recruit a sample of middle schools that is compositionally similar to the statewide proportions of locales, as indicated by the most recent Common Core of Data set available. We will recruit schools that enroll at least 40 percent minority students or at least 40 percent of students who qualify for free or reduced-cost lunch, to assess the program's effectiveness with respect to improving outcomes for high-need students. Schools will agree that participating teachers (in both treatment and control groups) will teach all four of the New York State standards related to middle school physics, ensuring that students have an equivalent opportunity to learn the content regardless of assigned condition. We will recruit districts, schools within districts, and pairs of teachers in schools to implement the block randomization. The target sample of students for RQ1 and RQ2 will include all students of participating treatment and control teachers' classrooms.

Power Analysis. We conducted power calculations for the comparisons between students receiving the Playground Physics intervention and those in the control group (RQs 1 and 2). The proposed design is a blocked cluster randomized design which assigns teachers/classrooms within schools to treatment or control. To calculate the number of schools needed for this study, we used the power equations for this design taken from Dong & Maynard (2013) and Schochet (2005). With 40 schools, each with 2 teachers, and 196 students per school (98 per teacher across 4 class periods), an assumed between-classroom (level 2) variance of .15, power of .80, alpha level of .05, a two-tailed test, and 15 percent attrition, we estimate the study has power to achieve a minimum detectable of .197. See Appendix G3 for details.

Student Measures. AIR will administer a pre/post knowledge assessment and student engagement and attitudes survey, in paper-and-pencil format, to students before and after their teachers provide instruction addressing learning objectives related to physics (either supplemented by Playground Physics or using only their regular curriculum). The **physics knowledge assessment**, developed for a previous study of the program, includes 20 multiple-choice items that align with the four New York State middle school science standards related to physics concepts (Appendix G provides further documentation for each student outcome measure). The assessment takes about 30 minutes to complete. After completing the physics knowledge assessment, students will complete a paper-and-pencil survey comprising three **survey scales** related to constructs of engagement in physics and attitudes towards physics. The survey is expected to take 15 minutes to complete. The "**Engagement with physics content** scale" will include items related to the students' experience of concentration, enjoyment, and interest while participating in physics lessons; this scale will be adapted from the "Engagement with science lessons" scale used by Friedman et al. (2017). The "**Interest in physics scale"** will include items related to students' interest in physics (e.g., "Physics is a topic that I enjoy studying" and "I would like to learn more about physics"), and will be adopted from the "Interest in science lessons" scale used by Friedman et al. (2017). The strong reliability and validity of these three measures were established in a previous study (Dhillon et al., 2016; see Appendix G for description of psychometric values of all outcomes measures). The latter two scales will be modified from the previous scales to focus specifically on physics; we will pilot test the revised scales with Cohorts 1 and 2 to evaluate the reliability and validity of the adapted scales using a Rasch analysis (Andrich, 1978; Wright & Masters, 1982) implemented with WINSTEPS (Linacre, 2005). Finally, the student survey will measure the "**Perceived utility of physics**," a valid and reliable scale adapted from Harackiewicz et al. (2016). Typical items include, "The material we are studying in this course is useful for everyone to know," and "The study of physics is personally important to me."

AIR will request **student administrative data** from the New York State Department of Education to obtain the demographic variables for each student to be included as covariates in the impact model: race/ethnicity (identifying sub-groups), gender, English language learner (ELL) status, student with disability (SWD) status, and free/reduced-price lunch eligibility status.

Student Outcomes Analysis. The analysis of the impact of Playground Physics on student outcomes will use the blocked cluster-randomized design described earlier (teachers randomly assigned within school). The main impact model for student outcomes will be a mixed-effects regression model, with the following general form:

$Y_{ijk} = \beta_0 + \beta_1 \mathrm{PP}_{jk} + \boldsymbol{\alpha}\mathbf{X}_{ijk} + \boldsymbol{\delta}\mathbf{W}_{jk} + \boldsymbol{\pi}\mathbf{S}_k + r_{jk} + \varepsilon_{ijk}$ where Y_{ijkl} represents the academic and attitudinal outcomes of student *i* nested in teacher *j* in school *k*. The treatment effect is measured by the coefficient β_1 for the treatment indicator (PP_{jk}). The model will also include student and teacher covariates represented by the covariate vectors $\mathbf{X}_{ijk}$ abd $\mathbf{W}_{jk}$, respectively. Student covariates will include demographic characteristics (as described above), grade level, and the pretest measures of the outcome being predicted by the model. Teacher covariates will include years teaching middle school physics at current school, years teaching at current school, years teaching middle school physics, and possibly attainment of a science degree. Furthermore, student covariates will be aggregated to serve as covariates at the teacher level to further increase the precision of the treatment effect. In addition, to account for the blocked randomization of teachers within schools, a vector of school fixed effects ($\mathbf{S}_k$) is included in the model. Covariates will be selected a priori for inclusion in the model to avoid researcher-induced bias due to covariate selection during impact modeling. The model includes a random effect for teachers (r_{jk}) along with the student error term (ε_{ijk}).

Descriptive Analysis of Relationships Among Implementation Fidelity and Outcomes. AIR will conduct descriptive and correlational analyses of the relationships between extent of participation in the PD/coaching model and classroom implementation of Playground Physics (RQ7) and teacher use of inquiry-oriented instruction when teaching physics (RQ8). AIR will use a previously validated scale that measures inquiry-oriented instruction (Meyers et al., 2015), with reported reliability of $\alpha = 0.84$, included in the Teacher survey (see Appendix G). AIR also will conduct descriptive and correlational analyses of the relationships between classroom implementation and students' knowledge of physics (RQ9) and their physics-related engagement and attitudes (RQ10).[1]

D.2. Evaluating Fidelity of Implementation. AIR will work with the project team to develop a fidelity of implementation matrix using a structured process (e.g., Goodson, Price, and Darrow, 2014) that defines each program component, indicators of that component, and cut points for adequate and high fidelity of implementation. AIR and NYSCI will adapt the matrix developed in our current evaluation of Playground Physics (which measures two of the four key components) for this study. The revised matrix will describe how to combine data from individual indicators to determine the fidelity of the overall component. Corresponding to RQs 3-6, there are four key program components included in the matrix: 1) coach participation in TtT workshop and follow-up support; 2) facilitation of professional development and coaching by NYSCATE coaches; 3) teacher participation in professional development and coaching; and 4) classroom implementation of Playground Physics. Each component may have multiple indicators (e.g., classroom

[1] We will use Kendall's tau to examine correlation because the distribution of implementation variables is unknown.

implementation will include both the number of units implemented and the amount of time spent on these units). The analysis of each component involves first determining the fidelity for individual coaches or teachers, then determining the overall level of fidelity for the indicator (e.g., the proportion of teachers meeting criteria for adequate or high fidelity for time spent on program), and then considering the fidelity levels of all of a component's indicators to determine the component-level fidelity. See Appendix G for a description of key components and indicators.

Implementation Data Sources. We will use four data sources to assess the implementation of the TtT model (RQ3): 1) Observation of the coach training sessions in 2019; 2) extant data from the online community of practice, 3) coach ratings of the effectiveness of the TtT workshops, collected via a post-workshop survey; and 4) administrative records of NYSCATE coach attendance of the different segments of the two-day workshop, and of the virtual coach check-in meetings. Data sources related to PD and coaching implementation (RQ4) and participation (RQ5) include teacher ratings of the effectiveness of the training for preparing them to implement the program collected via the post-workshop survey; administrative records of teacher attendance at PD sessions and virtual check-in meetings; and extant data on extent of participation of teachers in online CoP. The data source for the implementation of the Playground Physics curriculum (RQ6) is the Teacher Survey (completed by teachers within one week of the conclusion of their instruction related to physics), in particular, responses to items about the number of units and lessons implemented and the amount of time spent on Playground Physics.[2]

[2] Teachers in both conditions will complete this survey in order to establish the treatment-control contrast. The survey will also ask teachers to report the number of class periods they devoted to the instruction of force, motion and energy; these data will be used as a covariate in the statistical model of program impact.

REFERENCES

Andrich, D. (1978). A rating formulation for ordered response categories. *Psychometrika, 43*(4), 561—573.

Barab, S., MaKinster, J. G., Moore, J., Cunningham, D., & the ILF Design Team. (2001). Designing and building an online community: The struggle to support sociability in the Inquiry Learning Forum. *Educational Technology Research and Development*, 49(4), 71—96.

Brandt, W. C., Meyers, C., Molefe, A., Dhillon, S., & Zhu, B. (2012). The impact of eMINTS professional development on teacher instruction and student achievement: Year 1 report. *Washington, DC: American Institutes for Research.*

Campbell, P., Frances, J., Joly, B., Koh, H., Orfaly, R., & Whittemore, B. (2005). Brief report: Train the trainer as an educational model in public health preparedness. *Journal of Public Health Management*, S123-S127.

Campaign for Education Equity [CEE] (2012). Deficient resources: An analysis of the availability of basic educational resources in high-needs schools in eight New York State School Districts. NY: Author.

Csikszenymihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention*. New York: Harper Perennial.

Dede, C., Honan, J.P., & Peters, L. C. (eds.) (2005). *Scaling Up Success: Lessons from technology-based educational improvement*. San Francisco, CA: John Wiley & Sons, Inc.

Dhillon, G., Margolin, J.. Liu, F., & Williams, R. (2015). *Playground Physics implementation study*. Chicago, IL: American Institutes for Research.

Dong, N., & Maynard, R. (2013). PowerUp!: A tool for calculating minimum detectable effect sizes and minimum required sample sizes for experimental and quasi-experimental design studies. *Journal of Research on Educational Effectiveness*, *6*(1), 24-67.

Education Commission of the State [ECS] (2018). New York trends in 8th grade science scores, 2009-2015. Retrieved at https://www.ecs.org

Friedman, L.B., Margolin, J., Swanlund, A., Dhillon, S., & Liu, F. (2017). *Playground Physics Impact Study.* Chicago: American Institutes for Research. Available from www.air.org/playgroundphysics.

Funk, C., & Parker, K. (2018). Women and men in STEM often at odds over workplace equity. PEW Research Center.

Futuresource Consulting (2017). Sales of mobile PCS into the US K-12 education market continue to grow, as OS battle heats up. Press Article. Retrieved from http://futuresource-consulting.com/Press-K-12-Education-Market-Qtr4-0317.html

Goodson, B., Price, C., & Darrow, C. (2014). Measuring Fidelity. In C. V. Meyers and W. C. Brandt (Eds.), *Implementation fidelity in education research: Designer and evaluator considerations* (vol. 8, pp. 176-193). New York, NY: Routledge.

Gunckel, K. (2011). Mediators of a preservice teacher's use of the inquiry-application instructional model. *Journal of Science Teacher Education*, 22(1), pp. 79-100.

Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Priniski, S. J., & Hyde, J. S. (2016). Closing achievement gaps with a utility-value intervention: Disentangling race and social class. *Journal of personality and social psychology*, *111*(5), 745.

Harris, C. J., Penuel W. R., DeBarger, A. H., D'Angelo, C., & Gallagher, L. P. (2014). *Curriculum materials make a difference for next generation science learning: Results from year 1 of a randomized controlled trial.* Menlo Park, CA: SRI International.

Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, Make, Play: Growing the next generation of STEM innovators*. New York: Routledge.

Kuhn, D. (2009). Adolescent Thinking. In *Handbook of Adolescent Psychology*. NY: John Wiley & Sons, Inc.

Leadership Conference Education Fund [LCEF] (2015). Advancing equity through more and better STEM learning. Washington, DC: Author.

Lyon, G.H., Jafri, J., & St. Louis, K. (2012). *Beyond the pipeline: STEM pathways for youth development*. Special focus on STEM learning. Chicago, IL: AfterSchool Matters.

Margolin, J., Friedman, L. B., Swanlund, A., Dhillon, S. & Liu, F. (2017). *Playground Physics Impact Study*. Washington, D.C.: American Institutes for Research.

Marzano, R. J., & Simms, J. A. (2013). *Coaching Classroom Instruction*. Bloomington, IN: Marzano Research.

Meltzer, D. E., & Otero, V. K. (2015). A brief history of physics education in the United States. *American Journal of Physics*, *83*(5), 447-458.

Metzer, D.E., Plisch, M., & Vokos, S. (2012). *Transforming the Preparation of Physics Teachers: A Call for Action. A Report by the Task Force on Teacher Education in Physics (T-TEP)*. College Park, MD: American Physical Society.

Mundry, S., & Stiles, K. E. (Eds.). (2009). *Professional learning communities for science teaching: Lessons from research and practice*. NSTA Press.

National Assessment of Educational Progress [NAEP]. (2015). National Report Card. Washington, D.C.: U.S. Department of Education. Retrieved from http://www.nationsreportcard.gov.

National Science Board [NSB] (2018). *2018 Science & Engineering Indicators*. Washington, DC: Author.

National Science Foundation [NSF] (2015). Revising the STEM Workforce: A companion to science and engineering indicators 2014. Washington, D.C.: Author.

NCES (2018). Elementary/Secondary Information System [Dataset]. Retrieved from https://nces.ed.gov/ccd/elsi/

NGSS Lead States, (2013). *New Generation Science Standards: For states, by states*. Washington, D.C.: National Academies Press.

New York Equity Coalition [NYEC] (2018). *Within our reach: An agenda for ensuring all New York students are prepared for college, careers, and active citizenship*. NY: Author.

NYSCATE (2017). About Us. Retrieved from: http://www.nyscate.org/index.cfm

New York State Education Department [NYSED] (2017). *New York State P-12 Science Learning Standards*. NY: Author.

President's Council of Advisors on Science and Technology (PCAST). (2010). *Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future*. Washington, D.C.: Executive Office of the President.

Pollnow, M. (2012). *Implementing a K-12 Train the Trainer professional development model through the school improvement grant*. Retrieved from ERIC ProQuest LLC. (ED549704).

Pollnow, S., & Tkatchov, O. (2012). *The practical guide to teaching and learning*. Lanham, MD: Rowman & Littlefield.

Physics Teacher Education [PhysTEC] (2014). Physics teacher education. NY: Cornell University

Quinn, D.M. & Cooc, N. (2015). Science achievement gaps by gender and race/ethnicity in elementary and middle school: Trends and Predictors. *Educational Researcher*, 44(6), pp. 336-346.

Redmond-Sanogo, A., Angle, J., & Davis, E. (2016). Kinks in the STEM pipeline: Tracking STEM graduation rates using science and mathematics performance. School Science and Mathematics Journal, 116(7), pp. 378-388.

Robertson, A. D., Atkins, L. J., Levin, D. M., & Richards, J. (2015). What is responsive teaching? In A. D. Robertson, R. Scherr, & D. Hammer (Eds.), *Responsive Teaching in Science and Mathematics*. New York: Routledge.

Rothwell, J. (2013). The Hidden STEM Economy. Washington, D.C.: Brookings.

Sass, T.R. (2015). *Understanding the STEM pipeline*. Working Paper 125. National Center for Analysis of Longitudinal Data in Education Research & American Institute for Research.

Schochet, P. Z. (2005). *Statistical power for random assignment evaluations of education programs.* Princeton, NJ: Mathematica Policy Research.

Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. *Handbook of Creativity, 1*, 3-15.

Tipton, E., & Peck, L. R. (2016). A design-based approach to improve external validity in welfare policy evaluations. *Evaluation Review*, 39, pp. 167-178.

U.S. Department of Education, Office of Innovation and Improvement [USDE-OII]. (2016). *STEM 2026: A vision for innovation in STEM education*. Washington, D.C.: Author.

Wang, M.T., & Holcombe, R. (2010). Adolescents' perceptions of classroom environment, school engagement, and academic achievement. *American Educational Research Journal*, 47, pp. 633-662.

Wiener, R., and Pimentel, S. (2017). *Practice What You Teach: Connecting Curriculum & Professional Learning in Schools*. Washington, DC, The Aspen Institute.

Weiss, I. R., Heck, D. J., Pasley, J. D., Gordon, E. M., & Kannapel, J. P. (2010). *Designing for sustainability: Lessons learned about deepening teacher content knowledge from four cases in NSF's math and science partnership program.* Chapel Hill, NC: Horizon Research, Inc., http://www.mspkmd.net/cases/tck/sustainability/scale.pdf

Wenger-Trayner, E., & Wenger-Trayner, B. (2015). *Introduction to communities of practice: A brief overview of the concept and its uses.* Retrieved from http://wenger-trayner.com/introduction-to-communities-of-practice/

Westine, C. D., Spybrook, J., & Taylor, J. A. (2013). An empirical investigation of variance design parameters for planning cluster-randomized trials of science achievement. *Evaluation Review*, *37*(6), 490-519.

Wright, B. D., & Masters, G. N. (1982). *Rating scale analysis: Rasch measurement.* Chicago: MESA Press.