Next Generation Preschool Science: Findings from Design-based Research to Inform Iterative Development of an Innovative Curricular Program and a Field Study to Examine Implementation and Efficacy

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Background/Context. More than a decade ago, the comprehensive National Research Council report, Taking Science to School, highlighted the importance and need for introducing science early in childhood (National Research Council, 2007). Since then, this need has been echoed in preschool and prekindergarten standards, which highlight science as an important dimension of school readiness. For example, the Head Start Early Learning Outcomes Framework (U.S. Department of Health and Human Services, 2015) includes scientific reasoning as a key domain of school readiness that “provides opportunities for rich vocabulary learning and collaboration with peers and fosters a sense of curiosity and motivation to learn” (p. 51). Many preschool programs, however, offer children few opportunities to engage in science learning (Brenneman, Stevenson-Boyd, & Frede, 2009). Research suggests that preschoolers have significantly fewer opportunities to learn math and science than other readiness skills such as literacy (Early et al., 2010). Although science can be embedded in a wide range of activities, it is often misperceived as an isolated content domain and, therefore, opportunities to promote science across the day are often missed (Dominguez & Sharifnia, 2019). This is concerning given recent research documents science achievement gaps at kindergarten entry, especially in populations from economically disadvantaged backgrounds (Morgan, Farkas, Hillemeier, & Macsuga, 2016).

Researchers have worked to address the need for early science teaching and learning by developing professional development programs and curricula. Unfortunately, research to examine the impact of these programs on young children’s *science* learning has been limited. Some of these interventions have shown promise to improve instructional practices and learning in other domains such as vocabulary and literacy (French, 2004) and mathematics (Kinzie et al., 2014). However, effects on *science* learning have yet to be examined and/or detected. In addition, some of these programs require preschool programs to adopt new science-focused curricular frameworks and/or make substantial investments in professional development and time—often not possible for public preschool programs struggling to meet multiple systemic demands. Innovative resources that can be feasibly integrated with existing curricular frameworks and can be made widely available to preschool programs are very much needed.

Curriculum Program Developed and Goal of Research. The goal of our work was to address the need for interventions that yield improvements in science learning by developing and evaluating a research-based science curricular program that could be feasibly adopted in preschool, yet be powerful enough to yield significant improvements in science learning. To be easily integrated with existing preschool curricular frameworks, the program includes sample curricular activities that match the ecology of preschool classrooms and build on experiences that are common and interesting to young children. The program was uniquely designed to capitalize on innovative, developmentally appropriate uses of technology to support both early childhood teachers' instructional practices and young children's learning of science.

Research Design, Data Collection and Analyses. Our research and development effort included three phases—first developing the program (Co-Design Phase), later studying its implementation and efficacy (Field Study Phase), and finally examining its sustained use (Sustainability Phase). During the first phase, we engaged in a series of co-design activities through which researchers; curriculum and media developers; and preschool educators contributed to the development of curricular activities and apps. In this phase, we engaged in a series of design-based research (DBR) activities (Fishman, Penuel, Allen, Chen, & Sabelli, 2013); we collected and analyzed formative (observational and interview) data to inform iterations. In the second phase, we conducted an experimental field study to examine both implementation (via classroom observations and surveys) and the impact of the program (via observations of instruction and validated science assessments).

Context and Samples. Participants included Head Start and public Prekindergarten classrooms (teachers and children) serving predominantly children from low-income communities in CA and NY. The Co-Design Phase's sample included 4 classrooms. The Field Study Phase's sample included 20 classrooms; 10 classrooms were selected to implement the curricular program, while 10 classrooms were asked to continue with their usual practices. In order to maximize comparability across groups, classrooms were assigned to condition through a matched pair design. Variables used to generate matched pairs included type of program, teaching experience, prior training in science, and science curriculum used (if any). A subsample of approximately 10 children per classroom was randomly selected to conduct the standardized science assessment, prior to and after the implementation. Six out of the 10 teachers who implemented the program were still at their school the following year and were interviewed for the Sustainability Phase.

Findings and Conclusions. Findings from the DBR studies in the Co-Design phase yielded six major themes that informed the revisions to the teacher resources and learning activities. See Table 1. Field study findings from child assessment data suggests that children in classrooms that implemented the program made significant improvements in science learning, relative to children in classrooms that did not. See Table 2. The assessment used to examine children's science learning assessed a comprehensive list of science core ideas and practices. Given we developed the curriculum program as proof of concept, it addressed all of the science practices, but only a subset of core ideas. The significant effects detected, therefore, build on the growing evidence that highlights the importance of engaging children in science practices as a way to prepare them for understanding science core ideas. While children were not exposed to all of the science core ideas assessed in the assessment, engagement in science practices may have prepared to embrace science content in ways that may otherwise would have not been possible. While these findings are noteworthy, it is important to acknowledge that the effects observed while significant were small. Condition explained most of the variance at the classroom-level, where assignment occurred. However, the overall variance at the classroom-level was quite small. While this may be related to the measure itself, it also highlights the need to identify child-level factors that contribute to children's science learning, such as the experiences young children engage in at home/other informal learning contexts. Findings from the Field Study also indicated that children in classrooms implementing the curriculum program readily and successfully engaged in some science practices in the context of hands-on and digital activities (e.g., Observing and Describing, Comparing and Contrasting, Documenting Observations, Recording Data and, to some extent, Making Predictions). However, other practices were less often promoted by teachers. These more difficult practices included the practices of Questioning and Analyzing and Interpreting Data. Research to examine how best to support these practices in developmentally appropriate ways is needed.

References

Brenneman, K., Stevenson-Boyd, J., & Frede, E. C. (2009). Math and science in preschool: Policies and practice. Preschool Policy Brief, 19, 1-12.

Early, D. M., Iruka, I. U., Ritchie, S., Barbarin, O. A., Winn, D. M. C., Crawford, G. M., ... & Bryant, D. M. (2010). How do pre-kindergarteners spend their time? Gender, ethnicity, and income as predictors of experiences in pre-kindergarten classrooms. *Early Childhood Research Quarterly, 25*(2), 177-193.

French, L. (2004). Science as the center of a coherent, integrated early childhood curriculum. *Early Childhood Research Quarterly*, *19*(1), 138-149.

Fishman, B. J., Penuel, W. R., Allen, A. R., Cheng, B. H., & Sabelli, N. (2013). *Design-based implementation research: An emerging model for transforming the relationship of research and practice*. Teachers College Record, 115(14).

Kinzie, M. B., Whittaker, J. V., Williford, A. P., DeCoster, J., McGuire, P., Lee, Y., & Kilday, C. R. (2014). MyTeachingPartner-Math/Science pre-kindergarten curricula and teacher supports: Associations with children's mathematics and science learning. *Early Childhood Research Quarterly*, *29*(4), 586-599.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher, 45*(1), 18-35.

National Research Council. (2007). Taking science to school: Learning and teaching science in grades K-8. National Academies Press.

U.S. Department of Health and Human Services. (2015). *Head Start Early Learning*

Outcomes Framework. Retrieved from https://eclkc.ohs.acf.hhs.gov/hslc/hs/sr/approach/pdf/ohs-framework.pdf

Table 1

Co-Design Findings: Theme, Examples and Design Implications

Theme	Example	Design Implications
Theme 1: Certain activities did not promote target learning as expected.	Additional scaffolding was needed for teachers and children to successfully engage in some activities. For example, in Unit 2 (Force and Motion) teachers had difficulty scaffolding the idea that moving objects continue to move unless there is enough friction to slow them down or the object hits a "stopper."	Lessons were revised to include ways for teachers to scaffold learning and about the core science idea. For example, more opportunities for children to test what would happen when a "stopper" was placed in the path were added. The Teacher's Guide also included more information on science core ideas and how to scaffold learning.
	Format and user interface issues were addressed. For example, in the Unit 2 (Force and Motion) pilot study, we learned that watching the videos taken during ramps experiments did not allow children to process the details and results of experiments well enough because events occurred too quickly.	This led to the creation of a "Slow-it-Down" feature which allowed children to view a slow-motion version of their videos. This allowed for a more detailed review and nuanced discussions. An integrated audio narrative feature and step-by-step guidance was also created to help coordinate video recording and the actual rolling of objects down ramps.
Theme 2: It is necessary but not sufficient for digital tools to be "fun" and "engaging."	Coconut Star, for example, allowed children to manipulate just one variable at a time (e.g., ramp height, size of object, surface of pathway), but children would quickly disengage.	The app was altered to allow children to manipulate multiple variables at once to enhance playability and fun, but that also embedded scaffolds to help them focus on the isolated effects of each variable.

Theme 3: Each type of digital tool had unique affordances for learning; pilot study findings generated insight into how to take more advantage of those affordances to promote children's engagement with target science concepts and practices.	Videos and simulations help children's learning by extending beyond the confines of the classroom, as well as time and space. They provided unique opportunities for preschoolers to really "see" the science and discuss it.	Digital journals support teachers as they guide children through investigations. They allow children to document their experiments easily and more easily review findings. For example, a digital journal can store children's photos of their plants along with the measurements they took of the plants as it grows, and generate a child friendly graph for children to review.
Theme 4: Teachers at times were overwhelmed by the quantity and organization of information in the [printed] Teacher Guide. An interactive, digital guide was developed.	Teachers reported that they found the Teacher Guide very useful, but at times were overwhelmed with the amount of information included in it (it included detailed descriptions of the concepts and practices; lessons with detailed descriptions of activities; descriptions of the digital tools and activities, etc.).	An interactive, digital version of the Teacher Guide was designed to allow teachers to easily navigate and access different content. It included an overall unit calendar and a daily calendar that allowed teachers to sort activities by day or by activity format (i.e., circle time, center time), generating their own personalized calendar. Each activity description included a photo slideshow that included images of teachers and children engaging in that activity.
Theme 5: Classroom contexts varied across in a range of ways, including the structure of the school day and program, the needs of children, and teachers' experience. To promote effective implementation, the program needed to provide a balance of structured guidance and flexibility.	Surveys/interviews revealed that teachers with the least experience and/or low levels of comfort teaching science benefited the most from sample activities that included scripted instructions. Teachers with more experience typically used them as inspiration and made significant adaptations.	Sample adaptations were included in the Teacher Guide, and some activities were revised to make them easier for teachers to modify. For instance, teachers' ability to work in groups differed; some classrooms had to mostly work in large groups given physical or staffing constraints while others often formed small groups.

Table 2

Hierarchical Linear Modeling Results for Final Level 2 Model testing Curricular Effects

Fixed Effects	Coefficient	*df*	*t*-ratio
Intercept, β_{00}	0.284	18	0.032*
Condition, γ_{01}	0.303	18	0.035*
Sex, β_{10}	-0.170	151	0.191
Age, β_{20}	0.013	151	0.285
Fall Science total score, β_{30}	0.541	151	0.000***

* $p < .05$ *** $p < .001$