Abstract Title Page

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Title: Improving Mathematics Learning by Integrating Curricular Activities with Innovative and Developmentally Appropriate Digital Apps: Findings from the Next Generation Preschool Math Evaluation

Authors and Affiliations:

Ashley Lewis Presser, Education Development Center, Inc.
Philip Vahey, SRI International
Ximena Dominguez, SRI International

Abstract Body

Limit 4 pages single-spaced.

Background / Context:

This paper describes findings from a blocked randomized design (BRD) field study conducted to examine the *Next Generation Preschool Math* (NGPM) program's implementation in preschool classrooms and promise in improving young children's mathematic learning. NGPM integrates traditional preschool activities with developmentally appropriate technology to support teaching and learning. During development, an evidence-based curriculum design framework and iterative development processes were employed (i.e. design-based research).

The importance of promoting mathematics learning early in childhood has recently gained significant attention from policymakers, researchers and educators. Early mathematics learning is one of the strongest predictors of later mathematics achievement (e.g., Jordan, Kaplan, Ramineni, & Locuniak, 2009; NAEYC, 2010), and is also significantly associated with literacy and school readiness more broadly (Claessens & Engel, 2013; Duncan et al., 2007). While high-quality mathematics instruction can lead to improved academic outcomes, many teachers in public preschool programs feel unprepared to teach mathematics (Ginsburg, Lee, and Boyd, 2008; NRC, 2011) and find it difficult to integrate these areas of learning into an increasingly crowded curriculum (NAEYC, 2010). As a result, many preschool programs do not provide young children with rich opportunities to learn these important concepts and skills (e.g., Brenneman, Stevenson-Boyd, & Frede, 2009; Early et al., 2010; Ginsburg, Lee, & Boyd, 2008). When mathematics is taught, teachers tend to facilitate activities that focus on basic number and shape skills; however, providing children with opportunities to develop understanding of more sophisticated mathematics concepts such as quantity and rational number reasoning is critically important (e.g., Clements, 2004; Ginsburg, Lee, & Boyd, 2008). Curricular programs that support teachers and children in becoming robust mathematical thinkers are needed to better prepare children for the transition to elementary school.

Recent research suggests that technology, when used in developmentally appropriate ways, has unique affordances for improving teaching and learning in early childhood (e.g. Clements & Sarama, 2008; Linebarger & Piotrowski, 2009; Neuman, Newman, & Dwyer, 2010; Penuel et al., 2011; Sarama, 2004). Tablet-based games can provide unique opportunities to support learning (Lewis Presser, Vahey, & Zanchi, 2013) and complement hands-on experiences that use more traditional manipulatives already familiar to teachers and children (Clements & Sarama, 2004). Despite these documented affordances, integration of technology in early childhood classrooms is not common, partly due to the concerns about the effects of screen time on young children's health and well-being (AAP Policy Statement, 1999, 2011). Our approach for integrating digital technology, however, differs significantly from the extended, passive, and/or isolated exposure to developmentally inappropriate media that has been associated with potential harm. Instead, we use digital resources that enhance teaching and learning by spurring and supporting rich social interactions, and these digital resources complement effective, established teaching practices for preschool children involving hands-on experiences. Our approach is consistent with the National Association for the Education of Young Children's position statement (NAEYC, 2011) that teacher mediate the digital experiences to promote learning.

Purpose / Objective / Research Question / Focus of Study:

The main research questions were: (1) Does experiencing NGPM impact young children's mastery of subitizing and equipartioning? and (2) Can the NGPM units feasibly be implemented in preschool classrooms? In addition, we asked three exploratory research questions: (3) Does experiencing the NGPM unit 1 impact young children's mastery of subitizing?, (4) Does experiencing the NGPM unit 2 impact young children's mastery of equipartitioning?, and (5) Does experiencing the NGPM intervention improve general mathematics knowledge?

Setting:
The study took place in early childhood education centers in the New York City or San Francisco metropolitan areas, where researchers were located. Eligibility for study required that: (1) the center was located in the geographic area and serves at least 50% low-income children, (2) center directors agreed to participation of one classroom, (3) the classroom was not involved in any other research studies during the implementation period, and (4) the teacher agreed to participate in either group in keeping with the randomization procedure, attend NGPM Professional Development Training, and participate in data collection.

Population / Participants / Subjects:
A sample of 16 teachers from different early childhood education centers (i.e. one teacher per center) that serve low-income children participated in the study in the San Francisco Bay Area and New York City metropolitan areas. In order to account for potential unequal groupings, 8 blocks were created based on center level demographic variables (i.e., location, language) and randomization took place within each block. Approximately 8-10 children (169 children total) were randomly selected from each classroom to participate in the mathematics assessments. Groups were equivalent at baseline on both a distal (REMA) and proximal (NGPM) mathematics assessment. No classroom left the study, and only 3.6% of children who completed a pretest did not complete a posttest.

Intervention / Program / Practice:
We designed a set of research-based activities to introduce and help young children learn the important, but rarely taught, topics of subitizing and equipartitioning (Lewis Presser, Vahey, & Zanchi, 2013; Zanchi, Lewis Presser, & Vahey, 2013). A literature review and relevant learning standards resulted in a learning blueprint, which guided both the curricular activity development and assessment item development. These activities included both physical manipulatives and innovative tablet-based games that complemented each other, with a 5:1 ratio of physical manipulatives to digital games. The digital mathematics games developed comprises 8 complete games, four for each unit, and include a two self-leveling (e.g. increase in difficulty and provides teachers feedback on student performance), one collaborative (e.g. game that two children play on one table at the same time), and one "sandbox" (e.g. free play) game type in each unit.

Treatment teachers attended a full day professional development workshop prior to implementing the unit. This workshop addressed the mathematics content, typical difficulties children experience in learning the content, methods for teaching the specific content, a technology orientation, and overview of each digital game and non-digital activity. Each classroom was provided a set of five iPad tablets, one for the teacher and four for the children to use in a digital learning center, as well as all non-digital materials and books. Control teachers were provided the professional development and materials at the conclusion of the study.

Research Design:
A blocked randomized design was utilized to investigate the potential of NGPM to impact preschool children's knowledge of subitizing and equipartitioning. A BRD has the advantage of accounting for both observed and unobserved variables through randomization. Due to the small sample size, statistical power is a concern; however, BRD does not negatively impact power because the "n" is determined by the level at which randomization occurs, in this case at the classroom level (students nested within classrooms nested within blocks). In addition to concerns about statistical power, small samples are prone to unequal groupings even with randomization, so it is recommended to create blocks and randomize within each one (Hedges, personal communication). In order to account for any potential selection bias, students within each classroom were randomized to determine which students underwent testing (8-10 per class).

Data Collection and Analysis:
NGPM Assessment of children's mathematic knowledge. A standardized assessment was developed as part of the NGPM project to assess young children's subitizing and equipartitioning learning. This assessment was developed because there is currently no standardized assessment or subscale that targets these skills specifically. The assessment was developed to measure the *skills* targeted in the program, but not to be aligned to the *activities* included in the program. Alearning blueprint guided item development. The final battery was arranged in a flipbook format (one side contains instructions for assessors and the other side displays relevant images that are presented along with hands-on manipulatives to children). This battery was pilot-tested with preschool children by assessors who were trained to be reliable at 95% with assessment protocols. The psychometric properties of the assessment were then examined in an IRT framework using Winsteps (Linacre, 2003). Results from IRT analyses indicated that the battery had good reliability (.75 at pre-test and .76 at post-test), covered a wide range of item difficulty levels, and provided good coverage of the range of abilities represented in the study sample.

Feasibility of Implemenation. An adapted version of the Classroom Observation of Early Mathematics – Environment and Teaching protocol (COEMET; Clements & Sarama, 2008), was used to conduct classroom observations in both treatment and control classrooms. COEMET examines the correctness of mathematics content, teachers' ability to plan appropriate lessons, and classroom management and interpersonal interactions in the classroom. The COEMET has high levels of internal consistency (Cronbach's alpha = .94; Clements & Sarama, 2008) and is a good predictor (r = .50) of mathematics achievement. In addition, teachers were surveyed and interviewed about implementation use, successes, and challenges.

To address RQ 1, we used a 2-level HLM analysis with students (Level 1 units) nested within classrooms (Level 2 units) including condition and mean classroom level pre-test scores as covariates to improve precision. Proximal outcome measures typically show a higher effect size compared to distal outcome measure (i.e. those that measure general math knowledge), so even with a small sample, we are more likely to have the power to detect a change in our proximal indicator. Covariates will also increase the statistical precision, in this case pre-test scores (Bloom, 2005; Bloom, Richburg-Hayes, & Black, 2007). To address RQ 2, the classroom observation measure was analyzed through quantitative analysis of observer ratings and qualitative analysis of implementation themes. Exploratory RQ 3 -5 were analyzed using a 2-level HLM analysis with subscale or REMA scores. To address RQ 5, we also administered a general mathematics achievement test. The Research-Based Early Math (REMA) assessment was used in order to determine whether NGPM impact overall measure of mathematics achievement (e.g. distal outcome measures).

Findings / Results:

RQ (1) (Does experiencing NGPM (units 1 and 2) impact young children's mastery of subitizing and equipartioning?): A small-scale blocked randomized design was used to evaluate the potential effectiveness of the Next Generation Preschool Math (NGPM) units on student learning. Sixteen preschool classrooms were matched into eight pairs by school-level demographic variables and randomized within each pair into the experimental (NGPM) and control (business-as-usual) conditions. Approximately 10 children per classroom were individually tested for a total of 169 children. There was baseline equivalence between the groups at the beginning of the study. Initial findings (see Appendix Figure 1) suggest that the experimental group's post-test scores (M=59.69) were statistically different than the control group's (M=53.53) on the unit-specific content when classroom-level pretest scores were statistically controlled (p=.026, effect size=.51).

RQ (2) (Can the NGPM units feasibly be implemented in preschool classrooms?): Implementation findings from observations and interviews revealed that teachers found the materials and activities useful and were able to successfully integrate them in their classrooms to promote mathematics learning. In addition, a survey of preschool teachers who participated in the study showed an extremely high interest in the creation of additional materials.

Exploratory RQ's: Conditions differed significantly on subitizing subscale (RQ3), approached significant differences on the equipartitioning subscale (RQ4), and did not differ significantly on general mathematics knowledge (RQ5).

Conclusions:

The feasibility of the program's adoption in preschool classrooms is promising, particularly in light of growing interest in early childhood mathematics and the increasing access to technology in educational settings (NAEYC, 2011). Our NGPM research found that teachers successfully integrated the math activities into their current practices; the supplement nature of the program allowed them to complement their current curricula and the common activity formats helped them feel comfortable implementing suggested activities in their classroom. Although tablets are new resources to many preschool classrooms and represent an expense, they are becoming more available in schools. Teachers are becoming increasingly interested in using them for instruction and obtaining guidance on how to do so appropriately (Simon, Nemeth, & McManis, 2013). Our program's PD and resources provide guidance for teachers and our digital activities have been developed by following recommendations by NAEYC. Rather than requiring a computer per child as do some elementary school initiatives involving technology, our approach requires a small number of tablets (e.g., three to four per classroom) that are used in group formats and as part of a developmentally appropriate digital learning center. These study results provide preliminary evidence that NGPM improves preschool children's understanding of unit-specific mathematics content, was feasible to implement in preschool classrooms, and left teachers wanting additional units; thus, it adds credence to our approach of selectively integrating tablet-based games into the preschool learning environment.

Appendices

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Appendix A. References

References are to be in APA version 6 format.

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Appendix B. Tables and Figures
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Table 1. NGPM Pre- and Post- Test Scores by Condition