**Paper 4: Background / Context:** Education needs theoretically-grounded, empirically-tested (a) instructional materials (e.g., Feuer, Towne, & Shavelson, 2002; Kilpatrick, Swafford, & Findell, 2001; National Research Council, 2004; Reeves, 2002) and (b) models that scale up these materials successfully in diverse settings (Borman, 2007; Cuban & Usdan, 2003; McDonald, Keesler, Kauffman, & Schneider, 2006). Evaluations of both should include short-term and longitudinal research. We created both (a) an early mathematics curriculum developed using a comprehensive Curriculum Research Framework (CRF) (Clements, 2007) and (b) a similarly research-based model for scale up. We implemented them in the early childhood years, because long-range benefits to children are greatest for interventions in that period and because there is conflicting evidence as to whether the effects of early interventions persist or “fade.” Here we briefly present the three years of results from a longitudinal experimental evaluation this implementation, with an emphasis on the third and final year of the “follow-through” intervention.

Longitudinal evaluation is particularly important for the preschool and primary years. Some studies indicate that early interventions can have lasting effects. For example, several studies have shown positive and long-lasting effects of preschool experience (Broberg, Wessels, Lamb, & Hwang, 1997; Gray, Ramsey, & Klaus, 1983; Magnuson & Waldfogel, 2005; Montie, Xiang, & Schweinhart, 2006). However, there is considerable empirical research and resultant (practical) assertions that “preschool gains fade” in the primary grades. For example, in one study of six cohorts, gains in preschool weakened as children progressed through the primary grades, disappearing by fourth grade (Fish, 2003). Other studies show a similar fade (Natriello, McDill, & Pallas, 1990; Preschool Curriculum Evaluation Research Consortium, 2008; Turner & Ritter, 2004; U.S. Department of Health and Human Services — Administration for Children and Families, 2010). We designed and evaluated the effectiveness of Follow-Through treatment, testing our hypothesis that such follow through is the “missing piece” in many early interventions whose evaluations have found less positive effects.

Our theoretical framework is an elaboration of the Network of Influences model (Authors), illustrated in Figure 1. It is consistent with, but extends in levels of detail, such theories as diffusion theory and the overlapping spheres of influence (Rogers, 2003; Showers, Joyce, & Bennett, 1987). It applies to the preschool intervention and, recursively, to the longitudinal intervention—the follow through treatment—and its evaluation (see the lower right corner of Fig. 1).

**Purpose / Research Questions:** Our overarching research question was: What are the short- and long-range (persistence of) effects of the Building Blocks/TRIAD intervention, with and without follow through, on achievement? The present research included two experimental groups (and one control group). In both, pre-K teachers participated in the intervention. In the Follow-Through experimental group, teachers in grades K and 1 were taught about the pre-K intervention and ways to build upon it. Do both experimental groups outperform those in the comparison group in math achievement on the average, at the end of kindergarten and first grade? Do children in the experimental TRIAD Follow-Through (TRIAD-FT) group on the average outperform children in the TRIAD (non-follow through, TRIAD-NFT) experimental group (the value added question)? Are there significant moderators and mediators of effects?

**Setting:** The study took place in pre-K classrooms in two urban school districts, the
Participants: All schools in two urban districts whose pre-K teachers had not previously been involved in Building Blocks or TRIAD research or development projects were included. There was only 5% attrition, leaving a total of 1305 children with complete data on both pretest and posttest. By the end of the kindergarten and first grade years, the populations remaining in the original schools included the following: TRIAD-FT—K 348, 1st 272; TRIAD-NFT—K 335, 1st 242; and control—K 290, 1st, 257.

Intervention: The instructional approach of our early mathematics curriculum, Building Blocks is finding the mathematics in, and developing mathematics from, children’s activity (Authors). At the core of Building Blocks’ content and sequencing, and the core of the CRF, are empirically-established learning trajectories. We defined learning trajectories as “descriptions of children’s thinking and learning…and a related, conjectured route through a set of instructional tasks” (Authors, 2004, p. 83).

These learning trajectories also pervade the TRIAD (Technology-enhanced, Research-based, Instruction, Assessment, and professional Development) scale up model, including the subject-matter content, pedagogy, technology, assessments, and professional development. For example, they help teachers focus on the “conceptual storyline” of the curriculum, a critical element that is often missed (Heck, Weiss, Boyd, & Howard, 2002; Weiss, 2002).

The Follow Through treatment involved training teachers the learning trajectories, and then how such knowledge could be used to teach their regular mathematics curriculum. We used the software application, Building Blocks Learning Trajectories (BBLT), which provides scalable access to the learning trajectories via descriptions, videos, and commentaries (see Fig. 2). We also offered teachers supplementation of their curriculum with the Building Blocks Software, also based on learning trajectories (but, unlike the print materials, the software progresses to 3rd grade). The Follow Through professional development was also limited to only 5 days of training starting during the year of data collection.

Research Design: In a CRT design, schools were publicly assigned to one of three treatment groups (using a table of random numbers, with blind pointing to establish the starting number).

Data Collection and Analysis: All assessments were completed each year, including the Classroom Observation of Early Mathematics Environment and Teaching (COEMET) and child outcomes in math (Research-based Elementary Math Assessment, REMA; literacy and language assessments were also administered). Data were analyzed with HLM. Effect sizes were computed for significant main effects by dividing the regression coefficient by the pooled posttest standard deviation.

Findings: Pre-K. Pre- to posttest scores revealed that the Building Blocks children learned more mathematics than the control children (effect size, g = 0.76). Specific components of a measure of the quantity and quality of classroom mathematics environment and teaching in intervention and control classrooms partially mediated the treatment effect.

Pre-K and Kindergarten—Language and literacy. We also examined far transfer effects of the pre-K Building Blocks curriculum on oral language and literacy skills. There were no
effects on letter recognition. *Building Blocks* positively affected four oral language subscales, a persistent effect, given that the assessment was in the Fall of children’s Kindergarten year.

**Kindergarten—Math.** Consistent with the results from pre-K (in which the experimental treatments were identical), both experimental groups outperformed the control group in math achievement at the end of kindergarten (TRIAD-NFT ES = .34, *p* < .01; TRIAD-FT ES = .55, *p* < .01). However, contrary to our hypothesis, the TRIAD-FT did not statistically significantly outperform the TRIAD group (ES = .175, *p* > .05). Of the tested moderators (child-level-racial/ethnic group, gender, IEP status; school level—percentage of children who are English Language Learners and free/reduced lunch), only one was significant. Children identified as African American children in the TRIAD-FT group outperformed those in the other two groups when controlling for pre-K pretest (Control coeff: -.208, *p* < .0001; BB: -.214, *p* < .0001).

**First grade.** The TRIAD-NFT group was no longer significantly higher in math achievement at the end of first grade (ES = .20, *ns*). The TRIAD-FT group continued to outperform the control group (TRIAD-FT ES = .49, *p* < .01). See Figure 3. African American children displayed the lowest scores at first grade, and benefitted more from the TRIAD-FT intervention. There was not a significant main effect of gender, but there was a significant interaction between gender and the TRIAD-FT group. Girls performed lower than boys in the control group, about the same as boys in the TRIAD-NFT group, and slightly better than boys in the TRIAD-FT group.

**Mediators of the Follow Through treatment.** We tested COEMET variables as mediators. In Kindergarten, the Number of SMAs (Specific Math Activities) mediated the effect of the TRIAD-FT compared to Control treatment. Also, the Classroom Culture subscale mediated the effects of the TRIAD-FT compared to the TRIAD-NFT treatment (IE: .139, CI: .027 - .297), even when controlling for pre-K posttest as well as pretest—the "value added" condition (IE: .047; CI: .015 - .134). In First Grade, the Classroom Culture subscale was the only significant mediator.

**Conclusions:** The TRIAD implementation included a complete intervention in pre-K, but not in the subsequent two years. The pre-K *Building Blocks* intervention had practically and statistically significant effects on both mathematics and language. At the end of Kindergarten, both experimental groups outperformed the control group in math achievement at the end of kindergarten. However, contrary to our hypothesis, the TRIAD Follow Through did not statistically significantly outperform the TRIAD Non-Follow Through (TRIAD-NFT) group. Although it is encouraging that the gains of both TRIAD groups persisted, these findings did not support our hypothesis that Follow Through would be effective and necessary for this persistence. Nevertheless, the effect size of the TRIAD Follow Through group vs. the control group (.38) was greater than that of the TRIAD-NFT group (.30), so the trends were consistent with our expectations. Further, those trends did continue and all hypotheses were then supported. That is, by the end of first grade, the TRIAD-NFT group was no longer significantly higher than the control group. The TRIAD Follow Through group outperformed the control group and the TRIAD-NFT group.

Multiple studies have reported that preschool gains “fade.” This is often reported without adequate attention to the follow-up—more frequently, the lack of follow-up—planned and implemented for these children. We designed and evaluated the effectiveness of TRIAD’s Follow-Through treatment, testing our hypothesis that such follow through is
the “missing piece” in many early interventions whose longitudinal evaluations have found less positive effects. Children’s trajectories must be studied as they experience different educational courses. Treatment effects are relative, both in contrasting experimental and control groups and, longitudinally, to the nature of educational experiences these groups receive subsequently.

Even in our TRIAD Follow-Through treatment, multiple factors impeded implementation, including teacher’s views that district rules and “fidelity police” demanded following scripts and schedules exactly—and would not allow formative assessment or curriculum contraction. These factors were especially present at Kindergarten, when a new edition of the mathematics curriculum (unfortunately) coincided with the TRIAD implementation for that grade. Factors such as these appear to have led to the lack of significant differences between the TRIAD-NFT group and the TRIAD Follow Through group at that grade. First grade teachers had already implemented their new edition the previous year, and that may have helped them be more receptive to modifications and pedagogical strategies, such as formative assessment based on learning trajectories, that the TRIAD Follow Through Intervention emphasized.

These factors indicate that the Follow Through condition lacked elements of the TRIAD model (see descriptions in Authors, 2008). That is, the lack of a shared vision of teaching, and especially the constraints on school leaders' support of the innovation appeared to prevent learning trajectories from standing at the core of the first grade, and especially kindergarten, teachers' curriculum and teaching.

There was no evidence that the Building Blocks intervention was differentially effective for schools with different percentages of students with free or reduced lunch or English Language Learners, nor for individual children with or without IEPs. There was evidence that the intervention was differentially effective for one ethnic/racial comparison: African-American children learned less than other children in the same control classrooms and African-American children learned more than other children in the same Building Blocks classrooms in Kindergarten. It may be that the Building Blocks intervention is particularly effective in ameliorating the negative effects of low expectations for African-American children’s learning of mathematics (see National Mathematics Advisory Panel, 2008). In first grade, similar changes in expectations may have accounted for girls’ (vs. boys’) better performance in the TRIAD groups vs. the control group.

There are five basic recommendations. (1) Curriculum and policy should ensure that children, especially those living in poverty, should be provided with research-based, focused early mathematical interventions which can increase their knowledge of multiple mathematical concepts and skills (including, but also going beyond number). (2) It is essential that preschool mathematics interventions be continued into the primary grades. (3) The Curriculum Research Framework (Clements, 2007) upon which the curriculum was based has been repeatedly empirically supported and may serve as a useful guide to policy makers, curriculum and software developers, and administrators. (4) The learning trajectories at the core of the curriculum and TRIAD model may constitute a useful construct in future research, curriculum development, and professional development efforts. (5) This is the first study of this kind of which we are aware. We need more research on the conditions that children from early interventions enter in the primary school years.
Appendix A. References


Fish, R. (2007). Relationship between education intensity in kindergarten and grade 1 and the academic benefits of attending preschool. Doctoral dissertation, University of Buffalo, State University of New York, Buffalo, NY.


Appendix B. Tables and Figures

Figure 1: Revised Network of Influences Theoretical Framework*

* The “Follow Though” model at the bottom right, most relevant to this study, is simple a microcosm of the Framework. Contextual variables in dotted ovals include the school (A-D), teacher (E), and student (F-H) factors. For example, students’ socio-economic status, or SES (G), impacts children’s initial mathematics knowledge (H), which influences children’s achievement (R)—an outcome variable indicated by the solid rectangle. Implementation variables in solid ovals are features that the project can encourage and support, but cannot control absolutely. For example, heavy arrows from professional development (J), to teacher knowledge (N), to implementation fidelity (O), to student achievement (R), indicate the strong effects in that path. Support from coaches (L) also has a strong effect on implementation fidelity, while other factors (J, K, M) are influential, but to a moderate degree (not all small effects are depicted). Relationships are further described in the following section.
Figure 2  Building Blocks Learning Trajectories (BBLT) Web Application

BBLT provides scalable access to the learning trajectories via descriptions, videos, and commentaries. Each aspect of the learning trajectories—developmental progressions of children’s thinking and connected instruction—are linked to the other. For example, teachers might choose the instruction (curriculum) view and see the screen on the left, below. Clicking on a specific activity provides a description. Clicking on slides the screen over to reveal descriptions, several videos of the activity “in action,” notes on the video, and the level of thinking in the learning trajectory that activity is designed to develop, as shown below on the right. (See UBTRIAD.org for a demonstration.)
Clicking on the related developmental level, or student’s level of thinking, ringed above, switches to the view of that topic and that level of thinking. This likewise provides a description, video, and commentary on the developmental level—the video here is of a clinical interview task in which a student displays that level of thinking. Teachers can also study a development view, studying clinical interviews of children at each level of thinking, and, if desired, link back to activities.
Figure 3: Chart of Means of Mathematics Outcome Scores by Treatment and Time