Promoting Positive Transitions Through Coherent Instruction, Assessment, and Professional Development: The TRIAD Scale-Up Model

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Abstract The fundamental question of whether preschool effects "fade" is hotly debated in arenas of theory, research, and policy. Few of these debates consider the role of transitions. Might it be that poor transitions are at least partly to blame? That is, if transitions are neglected, present educational contexts may be unintentionally aligned against the long-lasting impact of early interventions. We conducted a series of studies of an implementation of a scale-up model that evaluated the persistence of effects of a research-based model for scaling up. The largest of these research projects was explicitly based on the theory that fade-out of effects would be mitigated by attention to transitions. Results indicated that the intervention condition that included the model's transition strategies maintained gains of the pre-K mathematics intervention better than the condition that did not include such strategies. However, more extensive and effective transition strategies should be developed and evaluated that expand on children's learning in preschool and thereby completely close equity gaps in mathematics through the primary grades.

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The fundamental question whether preschool effects "fade"[1] is hotly debated in arenas of theory, research, and policy. Some studies appear to show long-lasting effects, but many do not. There are multiple theories about why early effects might fade, but most evidence is descriptive or correlational. To bring some causal evidence to this important issue, we designed a large scale-up project based on our perspective, which is that fade-out may at least in part be a result of inadequate attention to transitions.

Built on this framework, the scale-up model is called TRIAD, for *T*echnology-enhanced, *R*esearch-based, *I*nstruction, *A*ssessment, and professional *D*evelopment. The TRIAD acronym suggests that successful scale-up must address the triad of essential components of any educational intervention—improving *instruction* by providing an empirically supported curriculum[2], promoting formative *assessment*, and supporting teachers' implementation of these with high-quality professional *development*—and that the model is based on research and enhanced by the use of technology. At the core of the TRIAD model is the use of research-based *learning trajectories*. Learning trajectories are "descriptions of children's thinking and learning in a specific mathematical domain, and a related, conjectured route through a set of instructional tasks designed to engender those mental processes or actions hypothesized to move children through a developmental progression of levels of thinking, created with the intent of supporting children's achievement of specific goals in that mathematical domain" (Clements & Sarama, 2004, p. 83). So, they have three components: a goal, a developmental progression, and an instruction fine-tuned to each level of that progression. We first instantiated the TRIAD model in the domain of early mathematics because such learning trajectories are well developed (National Research Council, 2009), not only for children of a given age but several years. This longitudinal nature affords the learning trajectories potential for supporting positive transitions. That is, as described in this chapter, they may support communication and connections across grades, providing connective tissue that will enhance the *coherence* of children's experiences.

Here our goal is to test hypotheses about how implementing the TRIAD model's transition strategies at scale may mitigate fade-out. The remainder of the chapter is organized into the following sections: (a) the historical context for that project, (b) TRIAD's theory of change and model—particularly as it addressed the fade-out

[1] The reason for the quotation marks is that we believe there are ramifications of the use of the term "fade-out." Although technically applied to the diminution of effect sizes, it is often interpreted as a *loss* of knowledge or skill or the evanescence of learning products or potential. This is consistent only with some theoretical interpretations and may be misinterpreted and misapplied to policy.

[2] The curricula used were an important component of the scale-up model and of the experiment, but this was a study of the *TRIAD scale-up model*, not only of a curriculum.

issue, (c) theories of the fade-out of early interventions, (d) TRIAD's design to address fade-out by supporting positive transitions, (e) TRIAD's implementation and research, (f) conclusions and implications, and (g) challenges the field faces and possible ways to meet them.

Historical Context: The Need for Early Mathematics Interventions at Scale

Although some research-based educational practices have shown promise in small-scale research studies, many have yet to be implemented at scale (Borman, 2007; Bornfreund, McCann, Williams, & Guernsey, 2014; McDonald, Keesler, Kauffman, & Schneider, 2006). The need is especially important in early mathematics, for at least four reasons. First, US proficiency in math is low (National Mathematics Advisory Panel, 2008). Second, students who live in poverty and who are members of linguistic and ethnic minority groups demonstrate significantly lower levels of achievement (Chernoff, Flanagan, McPhee, & Park, 2007; National Mathematics Advisory Panel, 2008) with that gap in the USA among the widest in 46 countries (Akiba, LeTendre, & Scribner, 2007). Third, such differences are evident from the earliest years (National Research Council, 2001, 2009; Sarama & Clements, 2009; Yuzawa, Bart, Kinne, Sukemune, & Kataoka, 1999). This is even more important because early mathematics competence predicts later achievement even into high school (National Mathematics Advisory Panel, 2008; National Research Council, 2009; Stevenson & Newman, 1986). Fourth, interventions to address these early differences appear to benefit low-resource and minority children because they have fewer educational opportunities in their homes and communities (Brooks-Gunn, 2003; Carneiro & Heckman, 2003; Natriello, McDill, & Pallas, 1990; Raudenbush, 2009). Unfortunately, most have not been taken to scale and often used the individual child as the unit of analysis, despite their assignment to treatments by class or school, which can inflate findings (Case, Griffin, & Kelly, 1999; for a review, see Clements & Sarama, 2011; Griffin & Case, 1997; Klein, Starkey, Clements, Sarama, & Iyer, 2008; National Mathematics Advisory Panel, 2008; Starkey, Klein, & Wakeley, 2004).

Any such scale-up project has to do a lot to succeed. However, there are additional challenges for those in the field of early childhood and another set of challenges for those focused on mathematics education. Early childhood, especially before kindergarten, includes settings and organizational structures that vary far more than do those at any other age level (Institute of Medicine (IOM) and National Research Council (NRC), 2015; National Research Council, 2009; Sarama & DiBiase, 2004). The workforce in those settings, their backgrounds, and their professional education are similarly diverse (Institute of Medicine (IOM) and National Research Council (NRC), 2015), with few incentives for individuals working in child-care centers or family child-care homes to seek specialized preparation for jobs that pay little more than minimum wage (Sarama & DiBiase, 2004). These can seem insuperable problems, given that the most critical feature of a high-quality educational environment is a knowledgeable and responsive adult and that high-quality professional development is essential to innovation (Darling-Hammond, 1997; National Research Council, 2001, 2009; Sarama & DiBiase, 2004; Schoen, Cebulla, Finn, & Fi, 2003).

The domain of mathematics is also challenging. Teachers must develop knowledge of subject-matter content they teach, the ability to communicate this content to children, and the ability to develop higher-order thinking skills. Teachers, especially teachers of young children, are not prepared to do so (National Council of Teachers of Mathematics, 1991; Sarama & DiBiase, 2004), with many resisting or rejecting any "academic" intervention, especially in mathematics (Clements, Fuson, & Sarama, 2017). Consistent with the wider US culture, many teachers believe that mathematics is a set of facts and that memorizing these facts is an appropriate route to learning mathematics. These beliefs are notoriously resistant to change, and they affect teachers' practices and their children's learning (Sarama & DiBiase, 2004).

In summary, scaling up high-quality mathematics education within early childhood settings holds particular challenges that range from the logistical (e.g., all-day professional development may be difficult to implement for teachers with emotionally dependent children) to the philosophical and motivational (is leaning mathematics truly important for very young children?) and the practical (many teachers lack knowledge of the content of mathematics, as well as its learning and teaching). A theoretical model of scaling up successful interventions must address these challenges if it is to support a high-quality implementation.

The TRIAD Model for Scale-Up: Theory of Change

The overarching theory for our research and our development of a scale-up model is an elaboration of the Network of Influences framework (Sarama, Clements, & Henry, 1998). This describes the relationships and influences that must be attended to achieve successful scale-up. Successful implementation of an intervention at scale involves multiple coordinated efforts to introduce, implement, and maintain the integrity of the vision and practices of an innovation through increasingly numerous and complex socially mediated filters (for details of the framework and its relationship to TRIAD, see Sarama, Clements, Wolfe, & Spitler, 2012).

Built on this framework, the TRIAD scale-up model's acronym suggests that successful scale-up should use appropriate technologies (*T*echnology-enhanced) and empirical evidence (*R*esearch-based) to address the triad of essential components (*I*nstruction, *A*ssessment, and professional *D*evelopment) of any educational intervention. Our definition of a successful scale-up is instantiation of an intervention in varied settings with diverse populations, addressing the needs of multiple sociopolitical stakeholders, to achieve satisfactory fidelity of implementation and, as a result, the intervention's goals for the maximum number of children including persistence of these effects. The remainder of this section summarizes the ten research-based guidelines in the TRIAD model, connecting it to the original Network of Influences theoretical framework (Sarama et al., 1998, 2012). Note that the TRIAD model was originally designed for all grades (and subject-matter domains), even if our instantiation has been in early mathematics.

1. *Involve and promote communication among key groups around a shared vision of the innovation* (Hall & Hord, 2001; Nyhan, 2015). Emphasize connections between the project's goals, standards, and societal need. Promote clarity of these goals and of all participants' responsibilities. School and project staff must share goals and a vision of the intervention (Bornfreund et al., 2014; Bryk, Sebring, Allensworth, Suppescu, & Easton, 2010; Cobb, McClain, de Silva, & Dean, 2003). This institutionalizes the intervention, for example, in the case of ongoing socialization and training of new teachers (Elmore, 1996b; Huberman, 1992; Kaser, Bourexis, Loucks-Horsley, & Raizen, 1999; Klingner, Ahwee, Pilonieta, & Menendez, 2003; Sarama et al., 1998).
2. *Promote equity* through equitable recruitment and selection of participants, allocation of resources, and use of curriculum and instructional strategies that have demonstrated success with underrepresented populations (Kaser et al., 1999; Moller, Stearns, Mickelson, Bottia, & Banerjee, 2014; O'Day & Smith, 2016).
3. *Plan for the long term.* Recognizing that scale-up is not just an increase in number but also of complexity provides continuous, adaptive support over an extended period of time. Plan an incremental implementation and use dynamic, multilevel, feedback, and self-correction strategies (Bryk et al., 2010; Coburn, 2003; Guskey, 2000). Communicate clearly that change is not a single event but a process (Hall & Hord, 2001).
4. *Focus on instructional change that promotes depth of children's thinking*, *placing learning trajectories at the core* of the teacher/child/curriculum triad to ensure that curriculum, materials, instructional strategies, and assessments are aligned with (a) national and state standards and a vision of high-quality education, (b) each other, and (c) "best practice" as determined by research, including formative assessment (Ball & Cohen, 1999; Bodilly, 1998; Bryk et al., 2010; Fullan, 2000; Higgins & Parsons, 2011; Kaser et al., 1999; Maloney, Confrey, & Nguyen, 2014; National Mathematics Advisory Panel, 2008; Nyhan, 2015; Raudenbush, 2008; Sowder, 2007; Wilson, Mojica, & Confrey, 2013). The learning trajectories serve as boundary objects (Akkerman & Baker, 2011; Wilson et al., 2013) that promote coherence and communication. This guideline is important for implementation with fidelity at any scale, although alignment is increasing important at larger scales and for transitions.
5. *Provide professional development that is ongoing, intentional, reflective, goal-oriented, focused on content knowledge and children's thinking, grounded in particular curriculum materials, and situated in the classroom and the school.* A focus on content includes accurate and adequate subject-matter knowledge both for teachers and for children. A focus on children's thinking emphasizes

the learning trajectories' developmental progressions and their pedagogical application in formative assessment. Grounding in particular curriculum materials should include all three aspects of learning trajectories, especially their connections (Clements, Sarama, Wolfe, & Spitler, 2015; Sarama & Clements, 2009). This also provides a common language for teachers in working with each other and other groups (Bryk et al., 2010; Wilson et al., 2013). Situated in the classroom does not imply that all training occurs within classrooms. However, off-site intensive training remains focused on and connected to classroom practice and is completed by classroom-based enactment with coaching—with coaches skilled in the innovation and in supporting teachers' learning and incorporation of new teaching practices (Clements et al., 2018; Jackson et al., 2014). In addition, this professional development should encourage sharing, risk taking, and learning from and with peers (Sarama, Clements, Starkey, Klein, & Wakeley, 2008). Aim at preparing to teach a specific curriculum and develop teachers' knowledge and beliefs that the curriculum is appropriate and its goals are valued and attainable. Situate work in the classroom, formatively evaluating teachers' fidelity of implementation and providing feedback and support from coaches in real time (Bodilly, 1998; Borman, Hewes, Overman, & Brown, 2003; Bryk et al., 2010; Cohen, 1996; Elmore, 1996b; Guskey, 2000; Hall & Hord, 2001; Kaser et al., 1999; Klingner et al., 2003; Pellegrino, 2007; Schoen et al., 2003; Showers, Joyce, & Bennett, 1987; Sowder, 2007; Zaslow, Tout, Halle, Vick, & Lavelle, 2010). As with guideline 4, this is important for implementation with fidelity at any scale. However, the planning, structures, common language, formative evaluation, and school-level context are increasingly important as the implementation moves to larger scales.

6. *Build expectations and camaraderie to support a consensus around adaptation*. Promote "buy-in" in multiple ways, such as dealing with all participants as partners and distributing resources to support the project. Establish and maintain cohort groups. Facilitate teachers visiting successful implementation sites. Build local leadership by involving principals and encouraging teachers to become teacher leaders (Berends, Kirby, Naftel, & McKelvey, 2001; Borman et al., 2003; Elmore, 1996b; Fullan, 2000; Glennan, Bodilly, Galegher, & Kerr, 2004; Hall & Hord, 2001).
7. *Ensure school leaders are a central force supporting the innovation and provide teachers continuous feedback that children are learning what they are taught and that these learnings are valued*. Leaders, especially principals, must show that the innovation is a high priority, through statements, resources, and continued commitment to permanency of the effort, with repeated communication with them so that the innovation is not forgotten (see guideline 10). An innovation champion leads the effort within each organization (Bodilly, 1998; Bryk et al., 2010; Glennan et al., 2004; Hall & Hord, 2001; Rogers, 2003, p. 434; Sarama et al., 1998).
8. *Give latitude for adaptation to teachers and schools, but maintain integrity*. Emphasize the similarities of the curriculum with sound practice and what teachers already are doing. Help teachers explicitly distinguish productive

adaptations from lethal mutation using specific activities (Brown & Campione, 1996). Also, do not allow dilution due to uncoordinated innovations (Fullan, 2000; Huberman, 1992; Sarama et al., 1998; Snipes, Doolittle, & Herlihy, 2002).

9. *Provide incentives for all participants, including intrinsic and extrinsic motivators linked to project work*, such as external expectations—from standards to validation from administrators. Show how the innovation is advantageous to and compatible with teachers' experiences and needs (Berends et al., 2001; Borman et al., 2003; Cohen, 1996; Darling-Hammond, 1996; Elmore, 1996a; Rogers, 2003).
10. *Maintain frequent, repeated communication, assessment ("checking up"), and follow-through efforts at all levels within each school district, emphasizing the purpose, expectations, and visions of the project, and involve key groups in continual improvement through cycles of data collection and problem solving* (Hall & Hord, 2001; Huberman, 1992; Jackson et al., 2014; Kaser et al., 1999; Snipes et al., 2002; U.S. Department of Education, 2016). Throughout, connections with parents and community groups are especially important to meet immediate and long-range (sustainability) goals.

Fade-Out of Early Interventions: Research and Theories

Although some studies indicate that prekindergarten interventions can have lasting effects (Broberg, Wessels, Lamb, & Hwang, 1997; Gray, Ramsey, & Klaus, 1983; Magnuson & Waldfogel, 2005; Montie, Xiang, & Schweinhart, 2006; Phillips, Gormley, & Anderson, 2016), most show such gains "fading" in the primary grades (ACF, 2010; Atchison, Diffey, & Workman, 2016; Claessens & Garrett, 2014; Natriello et al., 1990; Preschool Curriculum Evaluation Research Consortium, 2008; Puma et al., 2012; Turner & Ritter, 2004) or at best reveal mixed results (Bitler, Domina, & Hoynes, 2012; Hill, Gormley, & Adelstein, 2015). A recent meta-analysis on fade-out of early interventions involving nearly 1100 effect sizes taken from 65 studies reported an average impact of 0.26 SD but also that impacts decline by about 0.04 standard deviation units per year, which implies that program impacts persist, on average, for about 10 years (Leak et al., 2012).

There are at least five hypotheses about such fade-out (from Clements et al., 2018). First, the *learning begets learning* hypothesis (Carneiro & Heckman, 2003) posits that high-quality experiences result in greater school readiness and thus start a cascade of higher learning and achievement (Magnuson, Meyers, Ruhm, & Waldfogel, 2004). Second, the *inadequate potency* hypothesis attributes fade-out to the weakness and evanescence of the original intervention (ACF, 2010; Natriello et al., 1990; Turner, Ritter, Robertson, & Featherston, 2006). Third, the *latent trait* hypothesis holds that individual differences in children's later knowledge are more an indicator of stable, underlying characteristics related to learning and development throughout development (e.g., children's domain-general cognitive abilities, motivation, and external environments, such as home and school cultures) than of direct effects of early achievement on later achievement (Bailey, Watts, Littlefield, & Geary, 2014; Cooper, Allen, Patall, & Dent, 2010). Fourth, the *insidious insipid instruction* hypothesis (Clements, Sarama, et al., 2018) suggests that many educational contexts (e.g., minimal demands of curricula, standards, and teaching practices) unintentionally undermine persistence of effects of early intervention (Brooks-Gunn, 2003; Cooper et al., 2010; Ramey & Ramey, 1998). For example, after a successful pre-K experience, children may experience kindergarten and first-grade classrooms in which both the teachers and curricula assume little competence and target only early-developing skills (kindergarten and first-grade instruction often covers material children already know even without such pre-K experience, Engel, Claessens, & Finch, 2013). Teachers may remain unaware that some of their children have already mastered the material they are about to "teach" (Bennett, Desforges, Cockburn, & Wilkinson, 1984; National Research Council, 2009). Even if teachers are so aware, pressure to increase the number of children passing minimal competency assessments may lead some teachers to work mainly with the lowest-performing children. Within this context and without continual, progressive support, children's early gains appear to fade (cf. Robertson, 2015; Zhai, Raver, & Jones, 2012). Fifth, the *latent foundation* hypothesis (Clements, Sarama, et al., 2018) holds that any effects of building a foundation of comprehensive proficiencies may be revealed when the demands of instruction increase. This suggests that assessments in grades in which complexity increases the most may be more likely to evince the long-term effects of early development of such comprehensive proficiencies. For example, in mathematics, first grade is substantially more difficult than kindergarten (CCSSO/NGA, 2010; Engel et al., 2013; Powell, Fuchs, & Fuchs, 2013) especially in the increase in requirements for conceptual understanding (Schmidt, personal communication, May 9, 2016); and fifth grade shows a similar substantial increase in mathematical demands (CCSSO/NGA, 2010; Heatly, Bachman, & Votruba-Drzal, 2015; Pianta, Belsky, Vadergrift, Houts, & Morrison, 2008; Powell et al., 2013; Schmidt, Wang, & McKnight, 2005; Westat & Policy Studies Associates, 2001).

Thus, when we designed the TRIAD model, we knew we must also address the issue of fade-out as children move through the primary grades. The following section discusses how this model and its evaluation address these challenges and these hypotheses.

TRIAD and Transitions

The issue of fade-out was prominent in the work by many, including ourselves. For example, fade-out of general early childhood programs is a long-standing issue, and, for ourselves, the positive effects of our intervention in the Preschool Curriculum Evaluation Research (Preschool Curriculum Evaluation Research

Consortium, 2008) project—one of only a couple that had significant effects (Klein et al., 2008)—faded by the end of kindergarten (Preschool Curriculum Evaluation Research Consortium, 2008). Therefore, we designed the TRIAD model and the second evaluation to focus on the transitions from preschool to kindergarten and first grade.

Given that the TRIAD model was originally designed for all grades, an important principle of our implementation was that pre-K interventions alone cannot be expected to "inoculate" children against risks of school failure (Brooks-Gunn, 2003; Clements, Sarama, Wolfe, & Spitler, 2013; Sarama et al., 2012), and therefore the TRIAD model should be implemented in kindergarten and first grade as well as pre-K.

Beyond this basic principle, several aspects of the TRIAD model speak specifically to transitions across these grades. There may be no more important feature of the TRIAD model to support transitions than its core of learning trajectories. This construct allows teachers at different grades to see how development occurs *through* the grades and how some children at any grade are operating at the same level of thinking as certain children in earlier and later grades (Wilson et al., 2013). Thus, the learning trajectories become essential boundary objects (Akkerman & Baker, 2011; Cobb et al., 2003; Wilson et al., 2013) that serve as connective tissue, linking the standards, curricula, and practices of all the grades in early childhood and facilitating communication and coordination among teachers across these grades. Such coordination, and especially collaboration, supports children, especially African-American and Latino/a children (Moller et al., 2014, relevant to guideline #2). TRIAD's guidelines #1 and #6, emphasizing communication and camaraderie, are important to building and maintaining such coordinated efforts.

These communications and connections are especially important in the pre-K to kindergarten transition. Curricula designed for kindergarten often assume low levels of mathematical knowledge and often focus on lower-level skills (Engel et al., 2013). A culture of low expectations for certain communities and groups may support the use of such curricula (Boser, Wilhelm, & Hanna, 2014; O'Day & Smith, 2016). Teachers are often required to follow such curricula strictly and may have few means to recognize that children have already mastered or surpassed the content they are about to "teach" them (Bennett et al., 1984; Clements & Sarama, 2009a; National Research Council, 2009; Sarama & Clements, 2009; Thomas, 1982). Even if they do recognize children's competencies, pressure to increase the number of children passing minimal competency assessments may lead teachers to work mainly with (and/or mainly at the level of) the lowest-performing children. Communication between pre-K and kindergarten teachers based on learning trajectories has the potential to go beyond the typical "let's make sure we're not doing the same activities" to focus on children's levels of thinking and therefore a sharing of educational practices for children at certain levels regardless of the grade, and, more important in kindergarten, the possibility that kindergarten teachers welcoming children who experience high-quality pre-K education can consider more extensive changes, such as curriculum compacting or other strategies.

Implementation and Research

A series of studies evaluated the TRIAD model from pre-K to first grade, with the most recent analyses involving the cohort of children finishing their fifth-grade year. We used a cluster randomized (at the school level) experimental design that enabled a formal test of the generalizability of TRIAD's impact over the varied settings in which it was implemented. Participants were the 1305 children from the original 42 schools in Buffalo, NY, and Boston, MA, who had both a pretest and posttest in pre-K (Clements, Sarama, Spitler, Lange, & Wolfe, 2011) and the kindergarten and first-grade teachers in those schools. Schools were randomly assigned to three conditions, TRIAD in pre-K only, TRIAD with follow-through (TRIAD-FT) in kindergarten and first grade, and a business-as-usual control.[3]

In pre-K, then, both the experimental interventions implemented the Building Blocks curriculum (Clements & Sarama, 2013) using the TRIAD model (details are available in Clements et al., 2011). Basic results were that teachers implemented the intervention with adequate fidelity and that pre- to posttest scores showed that the children in the Building Blocks group learned more mathematics than the children in the control group (effect size, $g = 0.72$).

In the kindergarten year, the two TRIAD groups differed, with only the TRIAD-FT group engaged in the TRIAD model (this was repeated the following year). Kindergarten (and, a year later, first-grade) teachers in those schools assigned to TRIAD's follow-through condition were engaged in multiple activities. First, staff met with kindergarten and pre-K teachers on site at each follow-through school to facilitate an exchange of information between the pre-K teachers and kindergarten teachers regarding the particular mathematics knowledge and skills of children who had participated in the *Building Blocks* curriculum during the preceding year. TRIAD staff then worked with the 43 kindergarten teachers for seven sessions, spread over the intervention year, teaching them (a) about the pre-K intervention and what children learned (some pre-K teachers again presented on the latter) and (b) ways to build upon it in kindergarten. That is, teachers were shown, through example assessments items and videos, the mathematics that many of their entering children had learned. Teachers were also taught about the learning trajectories appropriate to their grade level (including levels of thinking common in contiguous grades), including the developmental progressions and how to modify their extant curricula to more closely match the levels of thinking of their children. That is, teachers discussed ways to use learning trajectories to support formative assessment (Clements & Sarama, 2009b, 2014; National Mathematics Advisory Panel, 2008; Sarama & Clements, 2009; Wilson, Sztajn, Edgington, & Myers, 2015). For example, they examined activities from their kindergarten mathematics curriculum and discussed how they could productively adapt them for children at different levels of

[3] To maintain focus, we do not describe all the ways that TRIAD's guidelines were implemented, such as planning for the long term by starting with these schools for the research, but from the start scheduling counterfactual schools and any new teachers for professional development after the cohort of children had completed those grades.

thinking along the learning trajectory for that topic. Some schools organized pre-K to grade 1 learning communities (Giles & Hargreaves, 2006) and invited project leaders to attend meetings. They also received access to the Building Blocks software (Clements & Sarama, 2007/2016), the same suite that the children had used in pre-K, which follows the learning trajectories through the primary grades.

In summary, the TRIAD-FT intervention provided kindergarten and first-grade teachers with professional development to develop their knowledge of the pre-K intervention and strategies for building on that knowledge using learning trajectories (Clements & Sarama, 2014; Sarama & Clements, 2009; Sztajn, Confrey, Wilson, & Edgington, 2012). We recognized that this was not a full curricular and pedagogical intervention such as that implemented in the pre-K TRIAD classrooms. The kindergarten and first-grade curriculum was "research-based," but not one based on learning trajectories as we define them. Thus, teachers of those grades would have had to impose a learning trajectories framework on a different curriculum, putting far more demands on the teachers who received less than half of the professional development for half of the time (1 year instead of 2). However, the intervention nevertheless served as an indirect test of our insidious insipid instruction hypothesis.

In addition, several unforeseen challenges confronted our vision for implementing these admittedly limited transition-based innovations. The year that the children started kindergarten, one district adopted a substantially revised version of their mathematics curriculum, the kindergarten level of *Investigations* (Investigations in number, data, and space, 2008), while the other district continued to use the first edition of the same curriculum. *Both* districts wrote and disseminated "pacing guides" that established what unit of the curriculum should be taught each week. For example, specific lessons were to be taught on specific days (e.g., lessons from the curriculum's "Day 1" on Oct. 7, lessons from "Day 2" on Oct. 8, etc.). The "walk-through" form used by administrators included items on this pacing guide. Teachers discussed the fact that any modifications using formative assessment, much less curriculum compacting, were all disallowed by what they called the district's "fidelity police." Efforts to institute the TRIAD guideline regarding communication were unsuccessful in most cases to change these opposing viewpoints.

Results showed the expected fade-out; that is, the effect size decreased for both experimental groups. Nevertheless, both TRIAD groups continued to outperform the control condition ($g = 0.46$ for the follow-through, $g = 0.30$ for the non-follow-through) at the end of their kindergarten year (Sarama et al., 2012). Differences were more pronounced at the end of first grade, with both experimental groups scoring significantly higher than control children ($g = 0.51$ for TRIAD-FT; $g = 0.28$ for non-follow-through), and TRIAD-FT children scored significantly higher than non-follow-through children ($g = 0.24$) (Clements et al., 2013). Analyses revealed just one consistent moderator. In all years, the TRIAD implementation was particularly beneficial for children who identified themselves as African-American. Mediators were complex, but again one was strongest and most consistent across the grades: The TRIAD follow-through intervention's effect was partially mediated by an increase in a positive classroom culture regarding mathematics thinking and learning.

At the time of this writing, we are analyzing the results of following this TRIAD cohort into their fifth-grade year. Without any intervention after first grade, the results continue to decrease for all groups. Effects were near-zero by fourth grade, but impacts on math achievement reemerged at fifth grade, and impacts were greatest on children who remained in their original assignment condition ("stayers") to receive the full dose of their respective treatments (Clements, Sarama, et al., 2018).

Challenges and Next Steps

Many challenges faced us during TRIAD's implementation, as they do any large-scale implementation. Bringing together diverse groups to support an intervention is alone a challenging task. Achieving an adequate level of fidelity of implementation presents challenges such as sufficient materials, technology, professional development, in-class support, and so forth. Supporting transitions between grades places additional demands on administrators, teachers, and staff. Each of these challenges requires both financial and social capital. A critical example of social capital is the essential support of school leaders, which drives improvements in all other components of the system (Bryk et al., 2010).

Turning to transitions, the follow-through treatment was, as we described, useful but too limited. Financial and logistical constrains kept us from implementing aligned curriculum in kindergarten and first grade and providing multi-year professional development. We are participating in new studies using different strategies, but more creative efforts are needed, such as starting in pre-K and implementing learning trajectories-based curriculum using the full TRIAD model for each consecutive year throughout elementary school. In general, too, the specific contribution of the learning trajectories per se, especially as connective tissue between grades, needs to be disentangled and identified. We are conducting a series of studies funded by IES to do so.

Conclusions and Implications

The best predictor of a successful academic career is early mastery of literacy and mathematical concepts and skills (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Duncan, Claessens, & Engel, 2004; Paris, Morrison, & Miller, 2006). Children from low-resource communities benefit more relative to children from higher-resource communities from the same "dose" of school instruction (Raudenbush, 2009). Thus, comprehensive implementations of research-based interventions may be especially effective in low-resource schools such as those in this project. This was the goal of our TRIAD project—to create a theoretically and empirically grounded model of scale-up and to increase knowledge of scaling up, and particularly the persistence of effects with and without follow-through, by conducting research that investigates the effectiveness of an instantiation of that model.

Evaluations at the pre-K level indicate that the TRIAD model shows promise in scaling up at least one educational intervention across a large number of diverse populations and contexts in the early childhood system. This evaluation supports major guidelines of the TRIAD model that involve the use of learning trajectories, contributing to the growing research corpus that supports the educational usefulness of learning trajectories, including evaluations of curricula built upon learning trajectories (Clements & Sarama, 2007, 2008; Sarama et al., 2008), elementary curricula based on related trajectories (Agodini & Harris, 2010), studies of successful teaching (Wood & Frid, 2005), and professional development projects (Bright, Bowman, & Vacc, 1997; Clarke et al., 2002; Wilson et al., 2015; Wright, Martland, Stafford, & Stanger, 2002). This supports the use of such structures in standards, such as the *Common Core State Standards* (CCSSO/NGA, 2010).

Although preschool is important—proficiency in math at the start of kindergarten accounts for the greatest decrease in the SES-math achievement gap (Galindo & Sonnenschein, 2015)—the primary grades must *build on* that positive start. Although effect sizes decreased in both groups, children in the TRIAD-FT group maintained their relative gains due to the interventions at kindergarten and first grade more than did children in the TRIAD group who did not have those transitions.

The TRIAD follow-through intervention's effect was partially due to the increase in the positive classroom cultures teachers develop. Interventions such as TRIAD may help engender a greater focus on mathematics, which in turn can help increase children's mathematics achievement. As other work has shown (Carpenter, Fennema, Peterson, & Carey, 1988; Clements et al., 2011; Jacobs, Franke, Carpenter, Levi, & Battey, 2001; National Research Council, 2009), helping primary teachers gain additional knowledge of mathematics, children's thinking and learning about mathematics, and how instructional tasks can be designed and modified—that is, the three components of learning trajectories—has a measurable, positive effect on their children's achievement.

The TRIAD-FT intervention especially helped narrow the achievement gap for African-American children. A high-quality, consistent mathematics education can make a demonstrative and consistent positive impact on the educational attainment of African-American children in the pre-K, kindergarten, and first-grade years compared to traditional instruction.

How do these results speak to the various hypotheses regarding the fade-out issues? First, there is no support for the most optimistic, learning begets learning, hypothesis. Effect sizes did decrease considerably. Our brief intervention (approximately 15–25 min per day) did not initiate a cascade of higher learning and achievement. This supports the notion that attending to transitions is critical.

It could be argued that our data is consistent with the second, inadequate potency, hypothesis. Again, the intervention was just a few (15–20) minutes per day and quite distinct from studies that compare an entire preschool program to children who attended no preschool. Thus, very large and lasting effects across domains would not be credible. However, in mathematics alone, although the effect size

(0.72 SD) in scale-up conditions was substantially smaller than in more controlled conditions during pre-K (in which effect sizes more than doubled this, Clements & Sarama, 2007), for a large-scale implementation of a relatively limited intervention, this must be considered at least a moderate effect (and greater than most, cf. Borman et al., 2003; Leak et al., 2012). Just as important, this hypothesis reifies the treatment effect as an entity that should persist unless it is "weak" and thus susceptible to fading. Such a perspective identifies the gain not as a snapshot of relative achievement but rather as a static object "carried by" the student that, if not evanescent, would continue to lift the student's achievement about the norm. Our theory (Sarama & Clements, 2009) does not share this view—that education and its effects are strictly about individual accumulation of knowledge.

The third, latent trait, hypothesis is supported by our analyses. This more pessimistic view is that stable characteristics are more influential than learning experiences over a limited time. The decrease in effect sizes across the entire follow-up period is consistent with the meta-analysis (Leak et al., 2012), with our decrease even greater at each year through the fourth grade, beginning with the greatest drop between the end of pre-K and the end of kindergarten of approximately 0.4 SD. We return to this issue after considering the other hypotheses.

Support was also given to two final hypotheses. The reemergence of significant effects at two critical point in elementary education—the transition to the increasing demands of the mathematics curricula of first and of fifth grade—supports the *latent foundation* hypothesis. Effect sizes at first and fifth grade were larger than impacts at kindergarten and fourth grade for both conditions, among all children and within all subgroups. It may be that children's early math learning helped them meet the greater mathematical demands introduced in first and fifth grades by building a foundation of comprehensive mathematics proficiencies. Because this was true for children in both TRIAD conditions, this may have been based on pre-K learning, rather than the follow-through intervention.

However, the decrease in effect size was greatest between pre-K and kindergarten—the latter a particularly unchallenging year (Engel et al., 2013). This finding supports the insidious insipid instruction hypothesis that the large decrease in the effect size was much more likely a "catch-up" than a "fade-out" phenomenon. Further, the decrease was less for the first-grade TRIAD-FT group than the first-grade TRIAD-NFT group, indicating that the follow-through work with first-grade teachers may have supported young learners in their transition to more challenging mathematics.

An implication of our results and the relative support for the various fade-out hypotheses is that children's trajectories must be studied as the children experience different educational courses. Intervention effects are relative, both in contrasting experimental and control groups and, longitudinally, to the nature of educational experiences the children in these groups subsequently receive. Although this might appear to be an issue of simple "educational engineering," the issue has substantial implications for both theory and policy. Interpretations of this "fade" often call for decreased funding and attention to pre-K (Fish, 2007). That is, if one accepts the inadequate potency hypothesis (even give substantial investments and efforts) or, more pessimistically, the latent trait hypothesis, it is not unreasonable to stop funding education in the early years. Although this may appear economically reasonable, we believe this mistakenly treats initial effects of interventions as independent of all future school contexts and of their interrelationships (alignment and continuity). Instead, we believe children's trajectories must be studied as they experience different educational courses and especially the transitions between consecutive years. If such effects "fade" in traditional settings but do not (or do not decrease as much) in follow-through interventions, then attention to and funding for follow-through efforts, including transitions from one grade to the next, for *both* pre-K and the primary grades should arguably increase.

Supporting this argument, our results and the implications we draw from them are consistent with other studies. For example, children from preschool intervention-enrolled classrooms, who transitioned to higher-performing elementary schools where the instructional quality was also high, maintained their initial learning gains, when compared to demographically similar children in the control group who also transitioned to higher-performing schools (Zhai et al., 2012). Children who are at-risk need continuing diagnosis and support (Brooks-Gunn, 2003; Mononen, 2014) using research-based learning trajectories (Salaschek, Zeuch, & Souvignier, 2014). This is the main lesson we learned from the TRIAD project: The sustainment of intervention effects requires the sustainment of high-quality, *connected*, *coherent* education based on research, including research on learning trajectories.

In summary, we agree that the latent trait hypothesis helps explain fade-out. However, there are two diametrically opposed implications that can be drawn from these findings. The "silver bullet" perspective holds that if pre-K effects are not sustained with no further support, we abandon pre-K and look for a different "magic" (Brooks-Gunn, 2003) alternative. (Few support such an approach to, say, one or more of the primary grades.) We take the position that the future well-being of both individuals and the society to which they can and would contribute are better served by improving preschools, all subsequent grades, and the coherence among them by fully implementing research-validated interventions, such as the TRIAD model across this span, to provide equitable support to all children in all grades.

References

ACF. (2010). *Head Start impact study. Final report*. Washington, DC: Office of Planning, Research and Evaluation, U.S. Department of Health and Human Services, Administration for Children and Families.

Agodini, R., & Harris, B. (2010). An experimental evaluation of four early elementary school math curricula. *Journal of Research on Educational Effectiveness, 3*, 199–253. https://doi.org/10.1080/19345741003770693

Akiba, M., LeTendre, G. K., & Scribner, J. P. (2007). Teacher quality, opportunity gap, and national achievement in 46 countries. *Educational Researcher, 36*, 369–387. https://doi.org/10.3102/0013189X07308739

Akkerman, S. F., & Baker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81*(2), 132–169. https://doi.org/10.3102/0034654311404435

Atchison, B., Diffey, L., & Workman, E. (2016). *K-3 policymakers' guide to action: Making the early years count*. Retrieved from http://portal.criticalimpact.com/go.cfm?a=1&eid=0ed9acd27591255409e5cb74f1f037a9&c=25742&jid=0c3e88797c6eeaf6&d=45ba92c4d715b2443947229f28c3afba.

Aunola, K., Leskinen, E., Lerkkanen, M.-K., & Nurmi, J.-E. (2004). Developmental dynamics of math performance from pre-school to grade 2. *Journal of Educational Psychology, 96*, 699–713. https://doi.org/10.1037/0022-0663.96.4.699

Bailey, D. H., Watts, T. W., Littlefield, A. K., & Geary, D. C. (2014). State and trait effects on individual differences in children's mathematical development. *Psychological Science*. https://doi.org/10.1177/0956797614547539

Ball, D. L., & Cohen, D. K. (1999). *Instruction, capacity, and improvement*. Philadelphia, PA: Consortium for Policy Research in Education, University of Pennsylvania.

Bennett, N., Desforges, C., Cockburn, A., & Wilkinson, B. (1984). *The quality of pupil learning experiences*. Hillsdale, NJ: Erlbaum.

Berends, M., Kirby, S. N., Naftel, S., & McKelvey, C. (2001). *Implementation and performance in New American Schools: Three years into scale-up*. Santa Monica, CA: Rand Education.

Bitler, M. P., Domina, T., & Hoynes, H. W. (2012). *Experimental evidence on distributional effects of Head Start*. Berkeley, CA: University of California, Berkeley.

Bodilly, S. J. (1998). *Lessons from New American Schools' scale-up phase*. Santa Monica, CA: RAND Education.

Borman, G. D. (2007). Designing field trials of educational interventions. In B. Schneider & S.-K. McDonald (Eds.), *Scale-up in education: Issues in practice* (Vol. II, pp. 41–67). Lanham, MD: Rowman & Littlefield.

Borman, G. D., Hewes, G. M., Overman, L. T., & Brown, S. (2003). Comprehensive school reform and achievement: A meta-analysis. *Review of Educational Research, 73*, 125–230. https://doi.org/10.3102/00346543073002125

Bornfreund, L., McCann, C., Williams, C., & Guernsey, L. (2014). *Beyond subprime learning: Accelerating progress in early education*. Washington, DC: New America.

Boser, U., Wilhelm, M., & Hanna, R. (2014). *Power of the Pygmalion effect: Teachers' expectations strongly predict college completion*. Washington, DC: Center for American Progress.

Bright, G. W., Bowman, A. H., & Vacc, N. N. (1997). Teachers' frameworks for understanding children's mathematical thinking. In E. Pehkonen (Ed.), *Proceedings of the 21st conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 105–112). Lahti, Finland: University of Helsinki.

Broberg, A. G., Wessels, H., Lamb, M. E., & Hwang, C. P. (1997). Effects of day care on the development of cognitive abilities in 8-year-olds: A longitudinal study. *Developmental Psychology, 33*, 62–69. https://doi.org/10.1037//0012-1649.33.1.62

Brooks-Gunn, J. (2003). Do you believe in magic? What we can expect from early childhood intervention programs. *Social Policy Report*, 17(1), 1; 3–14.

Brown, A. L., & Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In R. Glaser (Ed.), *Innovations in learning: New environments for education* (pp. 289–325). Mahwah, NJ: Erlbaum.

Bryk, A. S., Sebring, P. B., Allensworth, E., Suppescu, S., & Easton, J. Q. (2010). *Organizing schools for improvement: Lessons from Chicago*. Chicago, IL: University of Chicago Press.

Carneiro, P., & Heckman, J. J. (2003). Human capital policy. In A. B. Krueger & J. J. Heckman (Eds.), *Inequality in American: What role for human capital policies?* (pp. 77–239). Cambridge, MA: MIT Press.

Carpenter, T. P., Fennema, E. H., Peterson, P. L., & Carey, D. A. (1988). Teacher's pedagogical content knowledge of students' problem solving in elementary arithmetic. *Journal for Research in Mathematics Education, 19*, 385–401.

Case, R., Griffin, S., & Kelly, W. M. (1999). Socioeconomic gradients in mathematical ability and their responsiveness to intervention during early childhood. In D. P. Keating & C. Hertzman (Eds.), *Developmental health and the wealth of nations* (pp. 125–149). New York, NY: Guilford.

CCSSO/NGA. (2010). *Common core state standards*. Washington, DC: Council of Chief State School Officers and the National Governors Association Center for Best Practices.

Chernoff, J. J., Flanagan, K. D., McPhee, C., & Park, J. (2007). *Preschool: First findings from the third follow-up of the early childhood longitudinal study, birth cohort (ECLS-B) (NCES 2008-025)*. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Claessens, A., & Garrett, R. (2014). The role of early childhood settings for 4–5 year old children in early academic skills and later achievement in Australia. *Early Childhood Research Quarterly, 29*(4), 550–561. https://doi.org/10.1016/j.ecresq.2014.06.006

Clarke, D. M., Cheeseman, J., Gervasoni, A., Gronn, D., Horne, M., McDonough, A.,… Rowley, G. (2002). *Early Numeracy Research Project final report*: Department of Education, Employment and Training, the Catholic Education Office (Melbourne), and the Association of Independent Schools Victoria.

Clements, D. H., & Sarama, J. (2004). Learning trajectories in mathematics education. Mathematical Thinking and Learning, 6, 81–89. https://doi.org/10.1207/s15327833mtl0602_1

Clements, D. H., & Sarama, J. (2007). Effects of a preschool mathematics curriculum: Summative research on the Building Blocks project. *Journal for Research in Mathematics Education, 38*(2), 136–163.

Clements, D. H., & Sarama, J. (2007/2016). *Building Blocks software [computer software]*. Columbus, OH: McGraw-Hill Education.

Clements, D. H., & Sarama, J. (2008). Experimental evaluation of the effects of a research-based preschool mathematics curriculum. *American Educational Research Journal, 45*, 443–494. https://doi.org/10.3102/0002831207312908

Clements, D. H., & Sarama, J. (2009a). *Learning and teaching early math: The learning trajectories approach*. New York, NY: Routledge.

Clements, D. H., & Sarama, J. (2009b). Learning trajectories in early mathematics – Sequences of acquisition and teaching. In R. S. New & M. Cochran (Eds.), *Encyclopedia of language and literacy development* (pp. 1–6). London, ON: Canadian Language and Literacy Research Network.

Clements, D. H., & Sarama, J. (2011). Early childhood mathematics intervention. *Science, 333*(6045), 968–970. https://doi.org/10.1126/science.1204537

Clements, D. H., & Sarama, J. (2013). *Building Blocks* (Vol. 1 & 2). Columbus, OH: McGraw-Hill Education.

Clements, D. H., & Sarama, J. (2014). *Learning and teaching early math: The learning trajectories approach* (2nd ed.). New York, NY: Routledge.

Clements, D. H., Sarama, J., Spitler, M. E., Lange, A. A., & Wolfe, C. B. (2011). Mathematics learned by young children in an intervention based on learning trajectories: A large-scale cluster randomized trial. *Journal for Research in Mathematics Education, 42*(2), 127–166.

Clements, D. H., Sarama, J., Wolfe, C. B., & Spitler, M. E. (2013). Longitudinal evaluation of a scale-up model for teaching mathematics with trajectories and technologies: Persistence of effects in the third year. *American Educational Research Journal, 50*(4), 812–850. https://doi.org/10.3102/0002831212469270

Clements, D. H., Sarama, J., Wolfe, C. B., & Spitler, M. E. (2015). Sustainability of a scale-up intervention in early mathematics: Longitudinal evaluation of implementation fidelity. *Early Education and Development, 26*(3), 427–449. https://doi.org/10.1080/10409289.2015.968242

Clements, D. H., Sarama, J., Layzer, C., Unlu, F., Germeroth, C., & Fesler, L. (2018). Effects on executive function and mathematics learning of an early mathematics curriculum synthesized with scaffolded play designed to promote self-regulation versus the mathematics curriculum alone. *Submitted for publication*.

Clements, D. H., Fuson, K. C., & Sarama, J. (2017). The research-based balance in early childhood mathematics: A response to Common Core criticisms. *Early Childhood Research Quarterly, 40*, 150–162.

Cobb, P., McClain, K., de Silva, T., & Dean, C. (2003). Situating teachers' instructional practices in the institutional setting of the school and district. *Educational Researcher, 32*(6), 13–24.

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher, 32*(6), 3–12.

Cohen, D. K. (1996). Rewarding teachers for student performance. In S. H. Fuhrman & J. A. O'Day (Eds.), *Rewards and reforms: Creating educational incentives that work* (pp. 61–112). San Francisco, CA: Jossey Bass.

Cooper, H., Allen, A. B., Patall, E. A., & Dent, A. L. (2010). Effects of full-day kindergarten on academic achievement and social development. *Review of Educational Research, 80*(1), 34–70.

Darling-Hammond, L. (1996). Restructuring schools for high performance. In S. H. Fuhrman & J. A. O'Day (Eds.), *Rewards and reform: Creating educational incentives that work* (pp. 144–192). San Francisco: Jossey-Bass.

Darling-Hammond, L. (1997). *The right to learn: A blueprint for creating schools that work*. San Francisco: Jossey-Bass.

Duncan, G. J., Claessens, A., & Engel, M. (2004). *The contributions of hard skills and socio-emotional behavior to school readiness*. Evanston, IL: Northwestern University.

Elmore, R. F. (1996a). Getting to scale with good educational practices. In S. H. Fuhrman & J. A. O'Day (Eds.), *Rewards and reform: Creating educational incentives that work* (pp. 294–329). San Francisco: Jossey-Bass.

Elmore, R. F. (1996b). Getting to scale with good educational practices. *Harvard Educational Review, 66*, 1–25.

Engel, M., Claessens, A., & Finch, M. A. (2013). Teaching students what they already know? The (mis)alignment between mathematics instructional content and student knowledge in kindergarten. *Educational Evaluation and Policy Analysis, 35*(2), 157–178. https://doi.org/10.3102/0162373712461850

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

Fullan, M. G. (2000). The return of large-scale reform. *Journal of Educational Change, 1*, 5–28.

Galindo, C., & Sonnenschein, S. (2015). Decreasing the SES math achievement gap: Initial math proficiency and home learning environments. *Contemporary Educational Psychology, 43*, 25–38. https://doi.org/10.1016/j.cedpsych.2015.08.003

Giles, C., & Hargreaves, A. (2006). The sustainability of innovative schools as learning organizations and professional learning communities during standardized reform. *Educational Administrative Quarterly, 42*(1), 124–156.

Glennan, T. K., Jr., Bodilly, S. J., Galegher, J. R., & Kerr, K. A. (Eds.). (2004). *Expanding the reach of education reforms: Perspectives from leaders in the scale-up of educational interventions*. Santa Monica, CA: RAND Corporation.

Gray, S. W., Ramsey, B. K., & Klaus, R. A. (1983). The early training project 1962–1980. In Consortium for Longitudinal Studies (Ed.), *As the twig is bent… Lasting effects of preschool programs* (pp. 33–69). Mahwah, NJ: Erlbaum.

Griffin, S., & Case, R. (1997). Re-thinking the primary school math curriculum: An approach based on cognitive science. *Issues in Education, 3*, 1–49.

Guskey, T. R. (Ed.). (2000). *Evaluating professional development*. Thousand Oaks, CA: Corwin Press.

Hall, G. E., & Hord, S. M. (2001). *Implementing change: Patterns, principles, and potholes*. Boston, MA: Allyn and Bacon.

Heatly, M. C., Bachman, H. J., & Votruba-Drzal, E. (2015). Developmental patterns in the associations between instructional practices and children's math trajectories in elementary school. *Journal of Applied Developmental Psychology, 41*(6), 46–59. https://doi.org/10.1016/j.appdev.2015.06.002

Higgins, J., & Parsons, R. (2011). Professional learning opportunities in the classroom: Implications for scaling up system-level professional development in mathematics. *Mathematics Teacher Education and Development, 13*(1), 54–76.

Hill, C. J., Gormley, J. W. T., & Adelstein, S. (2015). Do the short-term effects of a high-quality preschool program persist? *Early Childhood Research Quarterly, 32*, 60–79.

Huberman, M. (1992). Critical introduction. In M. G. Fullan (Ed.), *Successful school improvement* (pp. 1–20). Philadelphia, PA: Open University Press.
Institute of Medicine (IOM) and National Research Council (NRC). (2015). *Transforming the workforce for children birth through age 8: A unifying foundation*. Washington, DC: National Academy Press.
Jackson, K., Cobb, P., Wilson, J., Webster, M., Dunlap, C., & Appelgate, M. (2014). Investigating the development of mathematics leaders' capacity to support teachers' learning on a large scale. *ZDM*. https://doi.org/10.1007/s11858-014-0652-5
Jacobs, V. R., Franke, M. L., Carpenter, T. P., Levi, L., & Battey, D. (2001). Professional development focused on children's algebraic reasoning in elementary school. *Journal for Research in Mathematics Education, 38*, 258–288.
Kaser, J. S., Bourexis, P. S., Loucks-Horsley, S., & Raizen, S. A. (1999). *Enhancing program quality in science and mathematics*. Thousand Oaks, CA: Corwin Press.
Klein, A., Starkey, P., Clements, D. H., Sarama, J., & Iyer, R. (2008). Effects of a pre-kindergarten mathematics intervention: A randomized experiment. *Journal of Research on Educational Effectiveness, 1*, 155–178.
Klingner, J. K., Ahwee, S., Pilonieta, P., & Menendez, R. (2003). Barriers and facilitators in scaling up research-based practices. *Exceptional Children, 69*, 411–429.
Leak, J., Duncan, G. J., Li, W., Magnuson, K., Schindler, H., & Yoshikawa, H. (2012). *Is timing everything? How early childhood education program cognitive and achievement impacts vary by starting age, program duration and time since the end of the program*. Irvine, CA: University of California, Irvine Department of Education.
Magnuson, K. A., & Waldfogel, J. (2005). Early childhood care and education: Effects on ethnic and racial gaps in school readiness. *The Future of Children, 15*, 169–196.
Magnuson, K. A., Meyers, M. K., Ruhm, C. J., & Waldfogel, J. (2004). Inequality in preschool education and school readiness. *American Educational Research Journal, 41*, 115–157.
Maloney, A. P., Confrey, J., & Nguyen, K. H. (Eds.). (2014). *Learning over time: Learning trajectories in mathematics education*. New York, NY: Information Age Publishing.
McDonald, S.-K., Keesler, V. A., Kauffman, N. J., & Schneider, B. (2006). Scaling-up exemplary interventions. *Educational Researcher, 35*(3), 15–24.
Moller, S., Stearns, E., Mickelson, R. A., Bottia, M. C., & Banerjee, N. (2014). Is academic engagement the panacea for achievement in mathematics across racial/ethnic groups? Assessing the role of teacher culture. *Social Forces*. https://doi.org/10.1093/sf/sou018
Mononen, R. (2014). *Early mathematics interventions: Supporting young children with low performance in mathematics*. Helsinki, Finland: University of Helsinki.
Montie, J. E., Xiang, Z., & Schweinhart, L. J. (2006). Preschool experience in 10 countries: Cognitive and language performance at age 7. *Early Childhood Research Quarterly, 21*, 313–331.
National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.
National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel*. Washington, DC: U.S. Department of Education, Office of Planning, Evaluation and Policy Development.
National Research Council. (2001). *Eager to learn: Educating our preschoolers*. Washington, DC: National Academy Press.
National Research Council. (2009). *Mathematics learning in early childhood: Paths toward excellence and equity*. Washington, DC: National Academy Press.
Natriello, G., McDill, E. L., & Pallas, A. M. (1990). *Schooling disadvantaged children: Racing against catastrophe*. New York, NY: Teachers College Press.
Nyhan, P. (2015). *The power of a good idea: How the San Francisco school district is building a prek – 3rd grade bridge*. Washington, DC: New America.
O'Day, J. A., & Smith, M. S. (2016). Quality and equality in American education: Systemic problems, systemic solutions. In I. Kirsch & H. Braun (Eds.), *The dynamics of opportunity in America* (pp. 297–358).

Paris, S. G., Morrison, F. J., & Miller, K. F. (2006). Academic pathways from preschool through elementary school. In P. Alexander & P. Winne (Eds.), *Handbook of research in educational psychology* (pp. 61–85). Mahwah, NJ: Erlbaum.

Pellegrino, J. W. (2007). From early reading to high school mathematics: Matching case studies of four educational innovations against principles for effective scale up. In B. Schneider & S.-K. McDonald (Eds.), *Scale up in practice* (pp. 131–139). Lanham, MD: Rowman and Littlefield.

Phillips, D. A., Gormley, W. T., & Anderson, S. (2016). The effects of Tulsa's CAP Head Start program on middle-school academic outcomes and progress. *Developmental Psychology, 52*(8), 1247–1261. https://doi.org/10.1037/dev0000151

Pianta, R. C., Belsky, J., Vadergrift, N., Houts, R., & Morrison, F. J. (2008). Classroom effects on children's achievement trajectories in elementary school. *American Educational Research Journal, 45*, 365–397.

Powell, S. R., Fuchs, L. S., & Fuchs, D. (2013). Reaching the mountaintop: Addressing the Common Core standards in mathematics for students with mathematical disabilities. *Learning Disabilities Research & Practice, 28*(1), 38–48. https://doi.org/10.1111/ldrp.12001

Preschool Curriculum Evaluation Research Consortium. (2008). *Effects of preschool curriculum programs on school readiness (NCER 2008–2009)*. Retrieved from Washington, DC: http://ncer.ed.gov/.

Puma, M. J., Bell, S., Cook, R., Heid, C., Broene, P., Jenkins, F., … Downer, J. T. (2012). *Third grade follow-up to the Head Start impact study final report, OPRE report # 2012-45*. Washington, DC: Office of Planning, Research and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services.

Ramey, C. T., & Ramey, S. L. (1998). Early intervention and early experience. *American Psychologist, 53*, 109–120.

Raudenbush, S. W. (2008). Advancing educational policy by advancing research on instruction. *American Educational Research Journal, 45*, 206–230.

Raudenbush, S. W. (2009). The Brown legacy and the O'Connor challenge: Transforming schools in the images of children's potential. *Educational Researcher, 38*(3), 169–180.

Robertson, J. (2015, November 7). In Tulsa, a hot spot for early childhood education, the grade is 'incomplete'. *The Kansas City Star*. Retrieved from http://www.kansascity.com/news/local/article43613463.html - storylink=cpy.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York, NY: The Free Press.

Salaschek, M., Zeuch, N., & Souvignier, E. (2014). Mathematics growth trajectories in first grade: Cumulative vs. compensatory patterns and the role of number sense. *Learning and Individual Differences, 35*, 103–112. https://doi.org/10.1016/j.lindif.2014.06.009

Sarama, J., & Clements, D. H. (2009). *Early childhood mathematics education research: Learning trajectories for young children*. New York, NY: Routledge.

Sarama, J., & DiBiase, A.-M. (2004). The professional development challenge in preschool mathematics. In D. H. Clements, J. Sarama, & A.-M. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 415–446). Mahwah, NJ: Erlbaum.

Sarama, J., Clements, D. H., & Henry, J. J. (1998). Network of influences in an implementation of a mathematics curriculum innovation. *International Journal of Computers for Mathematical Learning, 3*, 113–148.

Sarama, J., Clements, D. H., Starkey, P., Klein, A., & Wakeley, A. (2008). Scaling up the implementation of a pre-kindergarten mathematics curriculum: Teaching for understanding with trajectories and technologies. *Journal of Research on Educational Effectiveness, 1*, 89–119. https://doi.org/10.1080/19345740801941332

Sarama, J., Clements, D. H., Wolfe, C. B., & Spitler, M. E. (2012). Longitudinal evaluation of a scale-up model for teaching mathematics with trajectories and technologies. *Journal of Research on Educational Effectiveness, 5*(2), 105–135. https://doi.org/10.1080/19345747.2011.627980

Schmidt, W. H., Wang, H. C., & McKnight, C. C. (2005). Curriculum coherence: An examination of US mathematics and science content standards from an international perspective. *Journal of Curriculum Studies, 37*(5), 525–559.

Schoen, H. L., Cebulla, K. J., Finn, K. F., & Fi, C. (2003). Teacher variables that relate to student achievement when using a standards-based curriculum. *Journal for Research in Mathematics Education, 34*(3), 228–259.

Showers, B., Joyce, B., & Bennett, B. (1987). Synthesis of research on staff development: A framework for future study and a state-of-the-art analysis. *Educational Leadership, 45*(3), 77–87.

Snipes, J., Doolittle, F., & Herlihy, C. (2002). *Foundations for success: Case studies of how urban school systems improve student achievement*. Washington, DC: Council of the Great City Schools.

Sowder, J. T. (2007). The mathematical education and development of teachers. In F. K. Lester Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (Vol. 1, pp. 157–223). New York, NY: Information Age Publishing.

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly, 19*, 99–120.

Stevenson, H. W., & Newman, R. S. (1986). Long-term prediction of achievement and attitudes in mathematics and reading. *Child Development, 57*, 646–659.

Sztajn, P., Confrey, J., Wilson, P. H., & Edgington, C. (2012). Learning trajectory based instruction: Toward a theory of teaching. *Educational Researcher, 41*, 147–156. https://doi.org/10.3102/0013189X12442801

TERC. (2008). Investigations in number, data, and space (2nd ed.). Upper Saddle River, NJ: Pearson Scott Foresman.

Thomas, B. (1982). *An abstract of kindergarten teachers' elicitation and utilization of children's prior knowledge in the teaching of shape concepts*: Unpublished manuscript, School of Education, Health, Nursing, and Arts Professions, New York University.

Turner, R. C., & Ritter, G. W. (2004, April). *Does the impact of preschool childcare on cognition and behavior persist throughout the elementary years?* Paper presented at the American Educational Research Association, San Diego, CA.

Turner, R. C., Ritter, G. W., Robertson, A. H., & Featherston, L. (2006, April). *Does the impact of preschool child care on cognition and behavior persist throughout the elementary years?* Paper presented at the American Educational Research Association, San Francisco, CA.

U.S. Department of Education. (2016). *Case studies of schools implementing early elementary strategies: Preschool through third grade alignment and differentiated instruction.* Retrieved from Washington, DC: http://www2.ed.gov/rschstat/eval/implementing-early-strategies/report.pdf?utm_content=&utm_medium=email&utm_name=&utm_source=govdelivery&utm_term=.

Westat, & Policy Studies Associates. (2001). *The longitudinal evaluation of school change and performance (LESCP) in Title I schools: Final report*. Washington, DC: U.S. Department of Education, Office of the Deputy Secretary, Planning and Evaluation Service.

Wilson, P. H., Mojica, G. F., & Confrey, J. (2013). Learning trajectories in teacher education: Supporting teachers' understandings of students' mathematical thinking. *The Journal of Mathematical Behavior, 32*(2), 103–121. https://doi.org/10.1016/j.jmathb.2012.12.003

Wilson, P. H., Sztajn, P., Edgington, C., & Myers, M. (2015). Teachers' uses of a learning trajectory in student-centered instructional practices. *Journal of Teacher Education, 66*(3), 227–244. https://doi.org/10.1177/0022487115574104

Wood, K., & Frid, S. (2005). Early childhood numeracy in a multiage setting. *Mathematics Education Research Journal, 16*(3), 80–99.

Wright, R. J., Martland, J., Stafford, A. K., & Stanger, G. (2002). *Teaching number: Advancing children's skills and strategies*. London, ON: Paul Chapman/Russell Sage.

Yuzawa, M., Bart, W. M., Kinne, L. J., Sukemune, S., & Kataoka, M. (1999). The effects of "origami" practice on size comparison strategy among young Japanese and American children. *Journal of Research in Childhood Education, 13*(2), 133–143. https://doi.org/10.1080/02568549909594734

Zaslow, M. J., Tout, K., Halle, T. G., Vick, J., & Lavelle, B. (2010). *Towards the identification of features of effective professional development for early childhood educators: A review of the literature*. Retrieved from Washington, DC: http://www2.ed.gov/rschstat/eval/professional-development/literature-review.pdf.

Zhai, F., Raver, C. C., & Jones, S. M. (2012). Academic performance of subsequent schools and impacts of early interventions: Evidence from a randomized controlled trial in Head Start settings. *Children and Youth Services Review, 34*(5), 946–954.