Abstract Title Page

Title: Fadeout in an Early Mathematics Intervention: Same Old Schools or Underlying Skills?

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Abstract Body

Background / Context:

A consistent finding across early childhood interventions targeting mathematics and other achievement-related skills that is that initial treatment effects fade over time, with children not receiving the intervention catching up to children who did (Clements et al., 2013; Leak et al., 2010; Puma et al., 2010). One popular explanation for this is that, owing to their own preparation or a desire to ensure that all children receive basic skills training, elementary school teachers do not teach the kind of advanced content that children are prepared for after receiving an effective early mathematics intervention (Bodovski & Farkas, 2007; Crosnoe et al., 2010; Engel, Claessens, & Finch, 2014). Engel and colleagues (2014) found that most kindergarten teachers taught mathematics content at the level appropriate only for the lowest achieving students. Teachers reported spending more time on basic skills, such as counting and shape recognition, than any other skills, even though the majority of the children had already mastered these skills at school entry. A lack of exposure to advanced mathematical content may impose a ceiling on higher achieving children's subsequent mathematics achievement trajectories. Thus, children who benefit from early mathematics interventions may experience flatter achievement trajectories in subsequent years. In contrast, the lower achieving children who did not receive the intervention may benefit more from the basic level of instruction and catch up to their higher achieving peers. We refer to this hypothesis for fadeout of treatment effects in early mathematics interventions as the "same old schools" hypothesis.

An alternative hypothesis is short-run differences in mathematics achievement induced by interventions are soon overtaken by differences produced by relatively stable factors influencing children's long-term mathematical development. These factors likely include a combination of domain general cognitive abilities, relatively stable academic skills, motivation, and other factors that affect children's mathematics achievement across time. Consistent with this hypothesis, Bailey and colleagues (2014) found that correlations between children's mathematics achievement scores at different times during their mathematical development were accounted for in greater part by relatively stable factors across development than by unique effects of previous achievement on later achievement, though both types of effects were observed. If this is true, then children's higher mathematics achievement at the end of an effective early mathematics intervention might subsequently migrate to levels that would be predicted based on their underlying skills alone. We refer to this hypothesis for fadeout of treatment effects in early mathematics interventions as the "underlying skills" hypothesis.

Purpose / Objective / Research Question / Focus of Study:

The same old schools and underlying skills hypotheses generate different predictions about children's subsequent achievement trajectories following the conclusion of an effective early mathematics achievement intervention. The same old schools hypothesis posits that a lack of advanced instruction in early schooling imposes a ceiling on higher achieving children's mathematics learning. This ceiling should be present both for children whose skills were boosted by the intervention as well as control-group children who perform similarly to treatment-group children following the intervention.

The underlying skills hypothesis presumes that children in the control group with similar scores on the post-intervention assessment to children in the treatment group are advantaged on underlying skills, having reached the same level of achievement without the benefit of the effective early mathematics intervention. If this is true, the relatively high-achieving control

students who enter kindergarten with similar skills to their peers in the treatment group are predicted to experience greater achievement gains during the kindergarten year. We illustrate the conflicting predictions of the same old schools hypothesis and the underlying skills hypothesis in Figure 1.

(insert Figure 1 here)

We tested these two hypotheses using data from an effective early mathematics intervention. Specifically, we identified a subset of children in the control group with similar post-intervention achievement scores to children in the treatment group, and then tested whether their subsequent learning trajectories differed.

Setting:

The current study uses data from the Technology-enhanced, Research-based, Instruction, Assessment, and professional Development (TRIAD) intervention evaluation (Clements et al., 2011; Clements, Sarama, Wolfe, & Spitler, 2013), a study implemented in 42 low-resource schools designed to investigate the effects of the *Building Blocks* early mathematics curriculum. The intervention is described in greater detail below.

Population / Participants / Subjects:

At the intervention's conclusion, children were assessed immediately thereafter and then one year later in the kindergarten year. The overall sample includes 361 children in the control group and 418 children in the treatment group who had valid mathematics achievement score data in pre-kindergarten (the post-test) and kindergarten (the follow-up assessment). Children came predominantly from low income families: Eighty-five percent of students qualified for free or reduced price lunch. Descriptive statistics for this sample are presented in Table 1.

(insert Table 1 here)

Intervention / Program / Practice:

The intervention in the pre-kindergarten year included the *Building Blocks* mathematics curriculum and professional development for teachers in schools assigned to the treatment condition[1]. The control condition received business as usual. The curriculum produced substantial gains in the treatment group, and the treatment effect persisted into the third year of the study, but the effect diminished over time (Clements et al., 2013). Additional details about the *Building Blocks* curriculum are available in Clements & Sarama (2007).

Research Design, Data Collection, and Analysis:

Children's mathematics achievement was assessed immediately following the intervention (post-test) and then one year later in the kindergarten year (follow-up assessment), using the Research-based Early Mathematics Assessment (REMA). The measure is well validated and specifically designed for early mathematics (Clements, Sarama, & Liu, 2008). This measure defines mathematics achievement as a latent trait using the Rasch model, producing a score with a consistent metric that places children on a common ability scale (Bond & Fox, 2001; Clements et al., 2011).

[1] In the original TRIAD study, schools were randomly assigned to three conditions: (1) pre-kindergarten only treatment; (2) pre-kindergarten to first grade treatment; (3) control condition. Our analysis sample only included children who were in the pre-kindergarten only treatment and the control condition, since the largest fadeout effect occurred between these two groups.

To test both the underlying skills and same old schools hypotheses, we matched the treatment group to a subset of the control group with a similar mean and variance of mathematics achievement scores at the post-test. We then compared these groups' mathematics achievement scores at the follow-up assessment. The same old schools hypothesis predicts that these groups will score similarly at the follow-up assessment, while the underlying skills hypothesis predicts that children in the matched control group will outperform children in the matched treatment group.

To further test the underlying skills hypothesis, we then tested whether differences between the matched groups at the follow-up assessment were attenuated by a series of predictors. We regressed follow-up mathematics achievement on matched group and the following sets of predictors, adjusting for child age at the initial assessment and weighting by likelihood of being in the treatment group.

We tested whether differences between the matched groups at the follow-up assessment were attenuated by measures of socioeconomic status. Previous research suggests that poverty influences to children's academic achievement (Duncan et al., 1998). Therefore, it is possible that children in the matched control group outperform children in the matched treatment group on the follow-up assessment, because the matched control children come from less disadvantaged homes. Child covariates included whether the child received free or reduced price lunch measured in the kindergarten year (dummy coded as 0 or 1) and mother's highest level of education. For mother's level of education, we created dummy coded variables indicating the highest level of formal schooling the mother attained: no high school, high school, some college, college, or missing (with the mother attaining a high school diploma as the reference group).

To test the underlying skills hypotheses, we tested whether differences between the matched groups at the follow-up assessment were attenuated by children's literacy and language skills. Group differences in children's language and literacy skills might statistically contribute to higher achievement in matched controls on the follow-up assessment, because these skills may directly affect children's later achievement trajectories, and are likely correlated with domain general cognitive abilities (Deary, Strand, Smith, & Fernandes, 2007). Literacy skills were measured in the spring of kindergarten with the PALS – PreK (Invernizzi, Sullivan, Swank, & Meier, 2004) and MCLASS: CIRCLE (Landry, 2007). Both are commonly used literacy measures for early childhood programs, measuring recognition of upper and lowercase letters. Language skills were measured in the fall of kindergarten with the Renfrew Bus Story – North American Edition (Glasgow & Cowley, 1994).

Finally, we tested whether preschool fixed effects attenuated differences between the matched groups at the follow-up assessment. Before the study began, preschools in these two groups were grouped into blocks containing two of these schools with similar scores, and then schools were randomly assigned to the treatment or control group within block. Therefore, it is possible that children in the matched control group outperform children in the matched treatment group on the follow-up assessment, because their higher quality prior school experiences have better prepared them for future learning.

Findings / Results:

In the full sample, children in the treatment group outperformed children in the control group at the post-test assessment ($p < .001$). This effect faded out but remained statistically significant at the follow-up assessment ($p < .05$; Figure 2).

(insert Figure 2 here)

In the matched sample, children in both groups performed identically at the post-test assessment, and the matched control group significantly outperformed the matched treatment group at the follow-up assessment ($p < .001$; Figure 3). This pattern of results is consistent with the underlying skills model (Figure 1).

(insert Figure 3 here)

Table 2 shows the results of the regression models testing for which variables attenuate the difference between the matched groups at the follow-up assessment. The matched groups differed, adjusting for age (Model 0). The magnitude of this difference was reduced by 27% after adjusting for socioeconomic status (Model 1). Adjusting for language and literacy reduced the group difference by 95%, at which point it was no longer statistically significant (Model 2). Adjusting for preschool block reduced the group difference by 27%. When socioeconomic status, language, literacy, and preschool block were all included in the same model, adjusting for age, only literacy and language scores had statistically significant effects on children's follow-up mathematics achievement, and the difference between the matched groups was completely eliminated (Model 4). Taken together, these results suggest that children's language and literacy scores accounted for the difference between the matched groups' mathematics achievement at the follow-up assessment.

(insert Table 2 here)

Conclusions:

Children in the control group with similar post-test scores to children in the treatment group subsequently outperformed children in the treatment group, and this difference was almost completely accounted for by language and literacy, measures of children's underlying skills. Results support the underlying skills hypothesis account of fadeout of treatment effects for effective early mathematics interventions.

Though the same old schools hypothesis and the underlying skills hypothesis differ in their accounts of the processes underlying fadeout of treatment effects in early mathematics interventions, they have somewhat similar implications for boosting low achieving children's long-term achievement outcomes. Both hypotheses suggest the importance of changes in children's learning environments for sustaining treatment effects at their initial levels. The key difference between the two hypotheses relates to the type of instructional change likely to be most effective. The same old schools hypothesis suggests that treatment effects will be sustained if children are exposed to more advanced content in school after the intervention concludes. In contrast, the underlying skills hypothesis suggests two possible solutions. First, this hypothesis suggests that identifying intervening on non-mathematical skills that have relatively stable effects on children's mathematics achievement throughout development may reduce fadeout. Also, the underlying skills hypothesis suggests that an effective treatment might include additional high quality intervention for low achieving children, even after the conclusion of the initial effective early mathematics intervention. In other words, the most effective way to maintain relatively high levels of mathematics achievement produced by high quality interventions, such as *Building Blocks*, may be subsequent high quality interventions.

Appendices

Not included in page count.

Appendix A. References

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Appendix B. Tables and Figures

Table 1
Sample characteristics before and after matching on post-test mathematics achievement

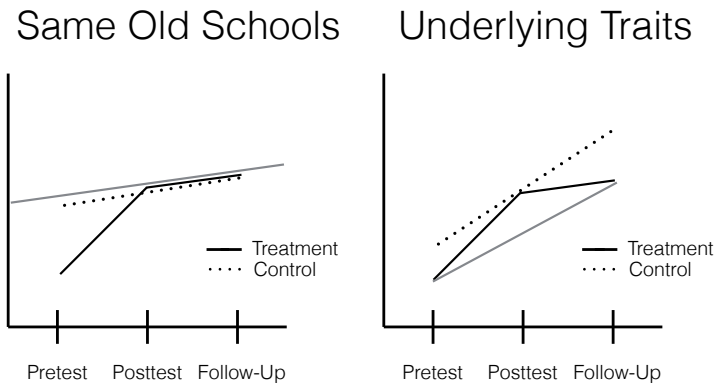
Variable	Treatment Mean (*SD*) or Proportion		Control Mean (*SD*) or Proportion	
	Before Matching	*After Matching*	*Before Matching*	*After Matching*
Mathematics achievement				
Pre-test	-3.25 (.86)	-3.45 (.86)	-3.17 (.80)	-3.00 (.74)
Post-test	-1.86 (.65)	-2.08 (.59)	-2.27 (.75)	-2.08 (.62)
Follow-up	-1.07 (.66)	-1.19 (.63)	-1.19 (.69)	-1.07 (.65)
Child characteristics				
Proportion Male	.50	.53	.50	.49
Age (in years at first pre-K assessment)	4.33 (.35)	4.29 (.36)	4.39 (.35)	4.40 (.35)
Proportion free and reduced price lunch	.82	.86	.88	.86
Language score (kindergarten)	-.78 (.87)	-.92 (.82)	-.99 (.93)	-.84 (.88)
Literacy score (kindergarten)	.55 (.28)	.51 (.28)	.56 (.26)	.60 (.25)
Maternal education (Proportions)				
Mother's education: No high school	.14	.16	.15	.13
Mother's education: High school	.32	.31	.31	.30
Mother's education: Some college	.39	.44	.33	.36
Mother's education: College	.15	.09	.20	.20

Table 2
Models testing for attenuation of the effect of matched group on follow-up mathematics achievement score

	Model 0	Model 1	Model 2	Model 3	Model 4
Matched group	-.22**	-.16*	-.01	-.18*	.02
	(.07)	(.07)	(.08)	(.08)	(.08)
Age at first test	.25***	.25***	.19***	.26***	.18***
	(.04)	(.03)	(.04)	(.04)	(.04)
Free or reduced price lunch		.04			-.12
		(.12)			(.12)
Mother's education: no high school		-.17			-.07
		(.13)			(.14)
Mother's education: some college		-.15			-.13
		(.10)			(.10)
Mother's education: college		.41**			.13
		(.13)			(.14)
Kindergarten literacy score			.35***		.35***
			(.04)		(.04)
Kindergarten language score			.21***		.22***
			(.04)		(.04)
Block fixed effects				Inc.	Inc.
Missing dummy variables		Inc.			Inc.
R^2	.10	.18	.32	.17	.37
Observations	576	576	397	576	397

Note. Standard errors in parentheses. All models are weighted likelihood of being in the treatment group. Missing dummy variables were included in the analyses to account for missing data on the socioeconomic status measures. Mathematics achievement outcome, literacy, and language scores were standardized to have a mean of 0 and standard deviation of 1.
* p<.05, ** p<.01; *** p<.001

Figure 1
Predicted Trajectories for Treatment and Higher Achieving Controls based on the Same Old Schools and Underlying Skills Hypotheses



Note. The gray line in the left panel represents a ceiling imposed by the low-level content of instruction, which constrains the later trajectories of children in the treatment group, according to the same old schools hypothesis. The gray line in the right panel represents the trajectory the treatment group would have been predicted to follow, had they not received treatment.

Figure 2
Mathematics Achievement Trajectories of the Intervention Groups Before Matching on Post-Test Mathematics Achievement

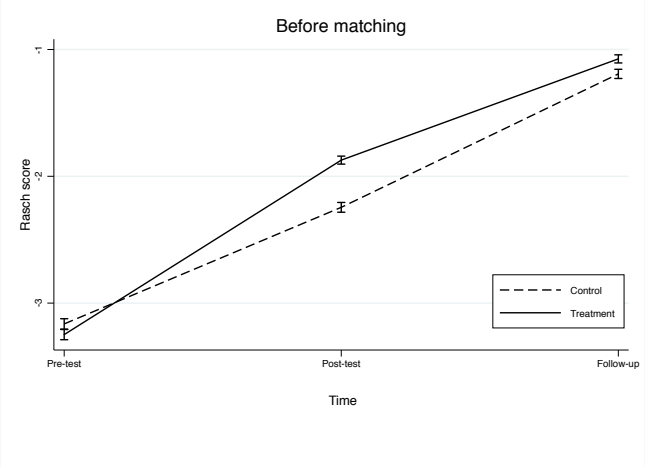


Figure 3
Mathematics Achievement Trajectories of the Intervention Groups After Matching on Post-Test Mathematics Achievement