Longitudinal Impact of Early Childhood Science Instruction On 5th Grade Science Achievement

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Nurtures

Networking **U**rban **R**esources with **T**eachers and **U**niversity to en**R**ich **E**arly Childhood **S**cience

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NURTURES
Uses the Complementary Learning Model

Increased academic achievement

+

Improved science comprehension

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NURTURES Program

Teacher Professional Development

Classroom Extension Activities (Family Packs)

Community Sci-FUN Events and WGTE Learning Segments

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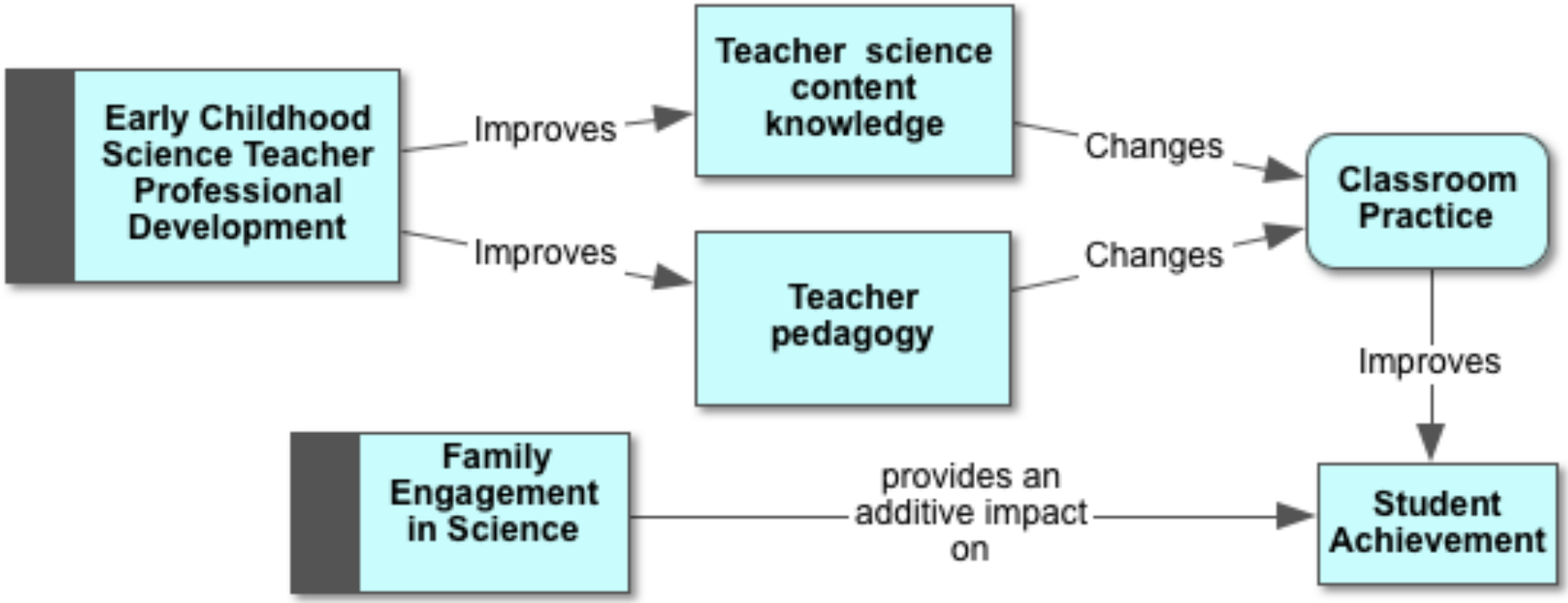
NURTURES Theory of Action



NURTURES Goals:

- increased science proficiency in PK-3 children
- align instructional practices of PK-3 teachers with K-12 Framework
- improve quality of family interactions while learning science together

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Aims of Study

- Key question: This study investigated if student placement in a grade 1-3 classroom with a teacher who had been trained in a Framework-aligned (NRC, 2012) professional development science approach impacted student science achievement in 5th grade as measured by the Science Subtest of the Ohio Achievement Assessment.

- To answer: Examine and describe the effect of NURTURES on students' academic performance at the school level

Sample Frame

Control and treatment students drawn from 41 out of 44 elementary schools in a large urban school district in the Midwest

School district is characterized by high racial diversity and 64.8% of students receiving free and reduced lunch

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Participants

Treatment Students:

Had at least one NURTURES teacher during the 2012-’13, 2013-’14, 2014-’15, or 2015-’16 academic years

Outcome Measure:

5th grade Ohio Achievement Science Subtest

Sample:

1588 – grade 5: 2-5 (**434** or **27.3 %** in intervention)

Participants

• Intervention was defined as having a NURTURES teacher at any point in grades **1-3**.

- For example, a student who was in 5th-grade in Spring 2017 would have been in 1-grade in 2012-'13 (first NURTURES intervention year), 2nd-grade in 2013-'14, 3rd-grade in 2014-'15, 4th-grade in 2015-'16 academic years, and therefore have more opportunities to have intervention teachers.

- Most intervention students had only 1 intervention teacher. Only 4% of intervention students in the sample had 2 intervention teachers.

- Multiple scenarios were possible due to retention of some students.

Table 1

*Demographic Characteristics of Participants in 5th-grade Ohio Spring 2017 Science Achievement Data (*N = *1588)*

Characteristic	*n*	%
Gender		
Female	752	47.4
Male	836	52.6
Ethnicity		
Asian	9	0.6
American Indian or Alaskan Native	1	0.1
African American	638	40.2
Hispanic/Latino	38	2.4
Multiracial	276	17.4
White	626	39.4
Retained in Grade		
Retained in any ‘12–‘13 through ‘15–’16 academic years in grades 1–4	78	4.9
Not retained	1510	95.1
Intervention		
Intervention teacher	434	27.3
Non-intervention teacher	1154	72.7

Baseline Equivalence – STAR EL Assessment as Covariate

• Fall scores for the **STAR Early Literacy** assessment for 1st-grade students in the study in 2012-'13 was used as a **covariate**. The covariate was school-mean centered to enhance interpretation.

• The partner district does not offer STAR Mathematics assessments in grades K-1, and only offers STAR Reading in grades K-1 to students who are already reading.

• **STAR Early Literacy** – STAR Early Literacy - 27- items are aligned to early literacy skills.

•Three broad domains used: Word Knowledge and Skills, Comprehension Strategies and Constructing Meaning, and Numbers and Operations

HLM

- The hierarchical model adopted in this study is a two-level random-slope hierarchical model, as implemented in R lme4. The technique is also known as multi-level analysis (M*plus*) or mixed regression models (STATA, SPSS).

- Models suitable for analysis of **grouped/nested** (e.g., students and teachers in schools) or **crossed** data structures (e.g., students or teachers changing schools over time), where the grouping/crossed factor(s) is/are conceived as random effects. The deviations and the amount of level-dependent random variation is estimated and incorporated in parameter estimates.

Bates, D., Maechler, M., Bolker, B., &, Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1−48. doi:10.18637/jss.v067.i01.

HLM and Missing Data

- Multiple-data imputations were used due to a large number of missing pre-test (K-level STAR EL data). **36.9%** of observations were missing at the pre-test level.

- Joint-modeling chained approach was used to estimate missing values for all variables simultaneously

- Pan algorithm using Markov Chain Monte Carlo (MCMC) technique as implemented in the R pan package (Zhao & Schafer, 2018) was used for both samples separately. Burn-in and imputation stages were performed.

- The burn-in phase uses iterations to stabilize estimation parameters, and the imputation phase draws replacement for missing values into the desired number of imputed datasets (Grund, Lüdtke, & Robitzsch, 2016).

Grund, S., Lüdtke, O., & Robitzsch, A. (2016). Multiple imputation of multilevel missing data: An introduction to the R package pan. *Sage Open, 6*(4). Retrieved from https://doi.org/10.1177/2158244016668220.

Zhao, J. H., & Schafer, J. L. (2018). Package 'pan': Multiple imputation for multivariate panel or clustered data. R package version 1.6. Retrieved from https://cran.r-project.org/web/packages/pan/pan.pdf

Model – Level 1

- The predictor variables in both samples:

Students' group or school mean-centered **STAR Early Literacy baseline measure**; **grade retention status** (levels: no = 0; yes = 1); **minority status** (levels: 0 = minority; 1 = non-minority or white), **gender** (0 = female; 1 = male), and **treatment condition** (0 = no NURTURES teachers in grades the following academic years: 2012-13, 2013-14, 2014-15; (1 = at least one NURTURES teacher in these academic years).

In practice students could have **more than one program teacher**, but this intervention variable was **dichotomized** to indicate either the presence or the absence of an intervention teacher. 4% of students in the sample had two intervention teachers.

Model – Level 2

- The **second-level** equations represented the effects of the schools (random intercepts only).

- Intervention slope was modeled.

- Level-2 model was unconditional or did not include school-context variables. The consequence was that no cross-level interactions were considered.

Model

Level-1 Equation Model

$$\text{Test Score}_{ij} = \beta_{0j} + \beta_{1j} \cdot (\text{Baseline Test Score}_{ij} - \text{Baseline Test Score}_{j}) + \beta_{2j} \cdot (\text{Grade Retention}_{ij}) + \beta_{3j} \cdot (\text{Minority Status}_{ij}) + \beta_{4j} \cdot (\text{Gender}_{ij}) + \beta_{5j} \cdot (\text{Intervention}) + r_{ij}$$

Level-2 Equation Model

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1j} = \gamma_{10}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$
$$\beta_{4j} = \gamma_{40}$$
$$\beta_{5j} = \gamma_{50} + u_{5j}$$

Mixed Model

$$\text{Test Score}_{ij} = \gamma_{00} + \gamma_{10} \cdot \text{School-Centered Baseline Test Score}_{ij} + \gamma_{20} \cdot \text{Grade Retention}_{ij} + \gamma_{30} \cdot \text{Minority Status}_{ij} + \gamma_{40} \cdot \text{Gender}_{ij} + \gamma_{50} \cdot \text{Intervention}_{ij} + u_{0j} + u_{5j} \cdot \text{Intervention}_{ij} + r_{ij}$$

Note. "*i*" denotes a student and "*j*" denotes a school.

Ohio Spring 2017 Science Achievement Results

Table 2

*Summary of Pooled Fixed Effects for 5th-grade Ohio Spring 2017 Science Achievement Data (*N *= 1588). Final Parameter Estimates and Inferences Obtained from 100 Imputed Data Sets.*

Fixed Effect	β	SE β	*t*-ratio	Approx. df	*p*
INTRCPT1, β_0					
INTRCPT2, γ_{00}	681.16	3.33	204.29	84942	<.001
SCHOOL-CENT. BASELINE slope, β_1					
INTRCPT2, γ_{10}	0.16	0.01	16.66	1774	<.001
RETENTION slope, β_2					
INTRCPT2, γ_{20}	-10.60	9.53	-1.11	133	.268
MINORITY STATUS slope, β_3					
INTRCPT2, γ_{30}	8.42	1.77	4.75	11120	<.001
GENDER slope, β_4					
INTRCPT2, γ_{40}	5.85	1.62	3.62	12704	<.001
INTERVENTION slope, β_5					
INTRCPT2, γ_{50}	6.14	2.15	2.86	37491	<.001

•The γ_{00} intercept value of 681.16 designated as γ00 represents a minority, non-intervention (no exposure to a NURTURES-trained teacher) student (average 1st-grade STAR early literacy baseline measure), who was not retained in a grade, and who obtained an average 5th-grade Ohio Science Achievement Assessment score in an average school.

Reading Results – Conditional Intra-Class Correlation (ICC)

- Conditional modeled ICC is 30.8%.
- It represents between-school variation over total variation.

Conclusions and Implications

- This study found that students from NURTURES treatment groups scored significantly higher on science tests given at fifth grade as compared to their peers.
- Overall, this study suggests that providing Framework-aligned science instruction, coupled with parent support, during early years improves science skills in later elementary grades.

Conclusions and Implications

- These findings provide evidence that access to science instruction in the early grades can help level the playing field for at-risk learners and mitigate the factors Morgan et al. (2016) have identified currently contribute to persistent lower science, math and reading achievement levels of at-risk youth.
- It also reinforces research by Allen & Kelly (2015) that suggests that early learning can impact later achievement.
- The findings of this study are consistent with those from Romance and Vitale (2017), which suggest that early science instruction has the benefit of increasing student academic achievement in science in later grades.
- These findings suggest that policy makers, school districts, and teachers aiming for increased science achievement in K-12 education need to start efforts in PreK-3 grades. Greater efforts should also be made by curriculum developers to infuse NGSS-aligned science into early grades.