Within-year Variance in Mathematics Growth Between Students, Teachers, and Schools

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NCAASE National Center on Assessment and Accountability for Special Education
Advancing research on growth measures, models, and policies for improved practice

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Abstract

Teachers and Schools both play important roles in students' education. Yet, the unique contribution of each to students' academic growth has rarely been explored. This study used a Bayesian estimator to parse variance in students' within-year growth into student, classroom, and school factors in Grades 3-5. Three cohorts of students were modeled with a weakly informative prior, arrived upon through a training dataset. The distribution of classroom effects (proxy for teacher effects) between schools was also examined, as well as the persistence of teacher effects across years.

Method

Measure. Measure of Academic Progress (MAP), developed by Northwest Evaluation Association (NWEA, 2011).

- Computer adaptive test designed to measure growth
- Vertical scale
- Administered during the fall, winter, and spring of each year

Sample. Five years of data collected in each of Grades 3-5.

- Three contiguous cohorts
  - Test sample
- Two noncontiguous cohorts in each grade
  - Training sample

Grade 3	Grade 4	Grade 5
2008-09	2008-09	2008-09
2009-10	2009-10	2009-10
2010-11	2010-11	2010-11
2011-12	2011-12	2011-12
2012-13	2012-13	2012-13
Analysis 1	Analysis 2	Analysis 3

Training sample

- Test sample *n* = 3,494 to 3,600 across grades
- ~75% eligible for free or reduced price lunch
- ~15% English Language Learners
- Predominantly Hispanic/Latino (> 50%), ~75% Non-White
- ~9% received special education services

Results

At Grade 3, roughly an equal amount of variance was attributable to classrooms and schools, while more variance was attributable to classrooms than schools in Grades 4 and 5.

Students in classrooms 1 *SD* above the norm progressed, on average, 2.19, 3.05, and 3.25 points more over the course of the school year in Grades 3-5, respectively. These correspond to 1.30, 2.36, and 2.20 additional months of "average" growth.

Students in schools 1 *SD* above the norm progressed, on average, 2.10, 1.91, and 2.20 points more annually.

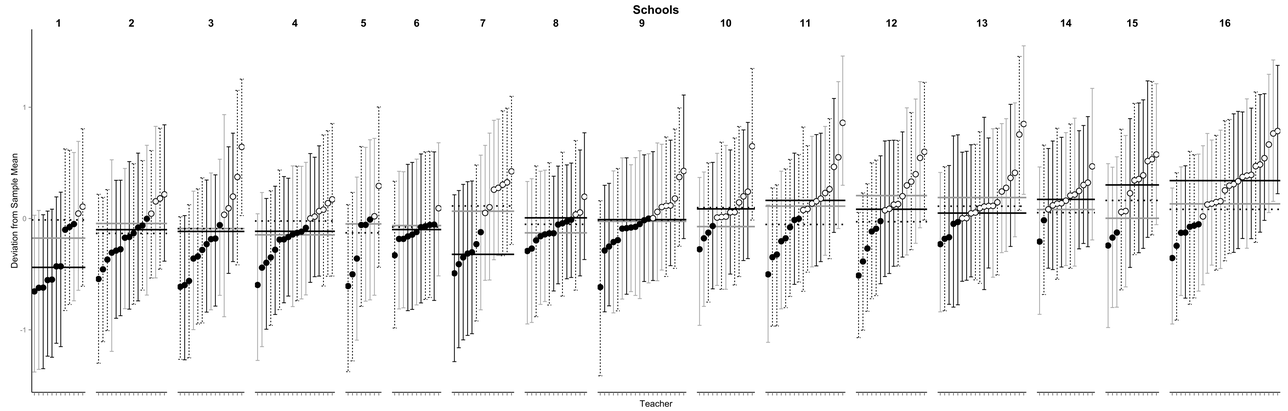
Unconditional Growth Model Results

Parameter	Grade 3				Grade 4				Grade 5			
	Post *M*	95% CI			Post *M*	95% CI			Post *M*	95% CI		
		Lower	Upper			Lower	Upper			Lower	Upper	
Intercept	187.62	185.69	189.55		199.17	196.77	201.52		208.10	205.40	210.78	
Monthly growth	1.69	1.57	1.83		1.39	1.26	1.51		1.48	1.34	1.62	
Random	Var	*SD*	95% CI		Var	*SD*	95% CI		Var	*SD*	95% CI	
			Low	Upp			Low	Upp			Low	Upp
Stu int	92.97	9.64	9.36	9.93	104.96	10.25	9.95	10.54	129.32	11.37	11.06	11.69
Stu slope	0.20	0.44	0.40	0.48	0.21	0.45	0.41	0.49	0.22	0.47	0.43	0.51
Tch int	8.83	2.97	2.38	3.63	16.62	4.08	3.30	4.98	33.40	5.87	4.75	7.11
Tch slope	0.05	0.23	0.18	0.29	0.10	0.32	0.25	0.38	0.11	0.34	0.27	0.41
Schl int	11.55	3.40	2.19	4.93	19.08	4.37	2.85	6.41	21.70	4.66	2.75	7.10
Schl slope	0.05	0.22	0.14	0.32	0.04	0.20	0.12	0.30	0.05	0.23	0.15	0.34
Residual	16.99	4.12	4.03	4.22	19.59	4.43	4.33	4.52	21.48	4.64	4.54	4.73
DIC	59255.57 – 59257.73				62276.72 – 62277.59				65558.99 – 65561.78			

Proportion of Slope Variance Between each Factor

Grade	Factor	Posterior Mean	95% Credible Interval	
			Lower	Upper
3	Students	60%	44%	74%
	Classrooms	18%	10%	26%
	Schools	22%	7%	42%
4	Students	56%	44%	67%
	Classrooms	32%	22%	43%
	Schools	12%	3%	24%
5	Students	56%	45%	67%
	Classrooms	31%	22%	41%
	Schools	13%	5%	24%

Distribution of classroom effects



Persistence

Grade 4
47% decay in classroom effect on status, negligible (negative) effect on growth

Grade 5
77% decay of Grade 3 effect, 24% decay of Grade 4 effect on status.

Grade 4 effect on growth was negative (*PM* = -0.24, 95% CI = -0.41, -0.06).

Analyses. Fully Bayesian multilevel growth model with weakly informative priors, fit with the MCMCglmm package (Hadfield, 2010) within the R statistical software (R Core Team, 2014).

Prior Specification

- Training dataset for each grade
  - Simple OLS model fit for each student (*Scores* on *Time*)
- Variance components specified according to the inverse Wishart distribution, $VC \sim W^{-1}(\mathbf{\Sigma}, \nu)$ with ν = 10, 5, and 3 for student, classroom, and school levels, respectively, and $\mathbf{\Sigma}$ specified according to the variances among OLS intercepts and slopes.
- Fixed effects (non-informative)
  $Pr(\mathbf{p}) \sim N(0, \mathbf{I}(1 \times 10^{10}))$
- Residual
  $Pr(\epsilon) \sim W^{-1}(1 \times 10^{-12}, 0.002))$

Model

Vector of MAP Math Scores, of length *d*.

Matrix of observation-level predictors (intercept & time).

Student-level matrix of intercept and growth predictors (non-White, Male, SPED, ELL [non, active, monitor], FRL).

Classroom-level matrix of intercept and growth predictors (demographic proportions).

School-level matrix of intercept and growth predictors (demographic proportions).

$$\mathbf{y}_d = \mathbf{X}^d\pi_d + \mathbf{X}^{st}\beta_i + \bar{\mathbf{X}}^c\gamma_j + \bar{\mathbf{X}}^{sc}\delta_k + (\mathbf{Z}^{st}\mathbf{s}_i + \mathbf{Z}^c\mathbf{c}_j + \mathbf{Z}^{sc}\mathbf{v}_k) + \epsilon$$

$$s_i \sim MVN\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}\sigma^2_{\hat{\alpha}_{stu}} & \rho\sigma_\alpha\sigma_\beta \\ \rho\sigma_\alpha\sigma_\beta & \sigma^2_{\hat{\beta}_{stu}}\end{pmatrix}\right)$$

$$c_j \sim MVN\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}\sigma^2_{\hat{\alpha}_{class}} & \rho\sigma_\alpha\sigma_\beta \\ \rho\sigma_\alpha\sigma_\beta & \sigma^2_{\hat{\beta}_{class}}\end{pmatrix}\right)$$

$$v_k \sim MVN\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}\sigma^2_{\hat{\alpha}_{schl}} & \rho\sigma_\alpha\sigma_\beta \\ \rho\sigma_\alpha\sigma_\beta & \sigma^2_{\hat{\beta}_{schl}}\end{pmatrix}\right)$$

Random effects design matrices for student, classroom, and school levels (only intercept and slope specified as randomly varying)

Operational definition of teacher effects.

Discussion

Overall Findings

- Students' growth varied considerably both between schools and between classrooms within school.
- Within-school variability in growth was generally greater than the between-school variability.
- Considerable evidence of differential classroom effects between schools.
  - Non-random assignment of teachers to schools.
  - Differential access to "high-growth" classrooms.
- Classroom effects decayed quite rapidly, and had small negative relations with subsequent growth.

Limitations:

- Extant data: Correlational design.
- Classroom-level random effects
- Stable subsample for persistence analyses
- Within-year growth assumed linear

Practical Implications:

- Results could be used at the district-level to help inform professional development decisions, and where to target district-wide resources. For example, schools with multiple classrooms displaying below-average growth, or specific "outlier" classrooms (low or high), may require further investigation (i.e., observations) to begin to determine specific factors influencing the growth (e.g., specific teacher behaviors, environmental stimuli, etc.).

References

- Hadfield, J. D. (2010). MCMC methods for multi-response generalized linear mixed models: The MCMCglmm R pacakge. *Journal of Statistical Software*, *33*(2), 1-22.
- Northwest Evaluation Association. (2011). Technical Manual For Measures of Academic Progress (MAP) and Measures of Academic Progress fro Primary Grades (MPG). Portland, OR.
- R Core Team. (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.