Abstract Title Page

Title: The Impact of a Research-Based Intervention on the Proportional Reasoning of Seventh-Grade Students with Mathematics Difficulties: A Regression Discontinuity Analysis

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Abstract Body

(Limit =1,000 words; Current = 988 words)

Title: The Impact of a Research-Based Intervention on the Proportional Reasoning of Seventh-Grade Students with Mathematics Difficulties: A Regression Discontinuity Analysis

Background and Focus of Study:

Ratio and proportional relationships, along with the interrelated topics of fractions, decimals, and percent, provide a critical foundation for algebra (National Mathematics Advisory Panel, 2008). Proportional reasoning, which not only requires understanding the concept of ratios and that two or more ratios are equal, also requires the ability to extract relevant information to develop a representation of the problem situation and is challenging for many children and adolescents, especially students with mathematics difficulties (Özgün-Koca & Altay, 2009). The intervention investigated in this study represents an approach to proportional problem solving via schema-based instruction (SBI). Jitendra, Harwell, Dupuis, and Karl (2017a) examined the effectiveness of SBI for a subsample of students with mathematics difficulties (MD) selected from a randomized cluster study (Jitendra et al., 2015). Based on a sample of 806 students classified as MD clustered within 82 classrooms, Jitendra et al. (2017a) reported SBI on average improved student scores on a posttest and delayed posttest of proportional problem solving (PPS) administered 9 weeks after treatment compared to a control condition, suggesting SBI could be used effectively for students classified as having MD in the short and longer term. This finding raises an important question: What is the range of proportional reasoning skills and general mathematical proficiencies for which SBI enhances student performance? The present study used a regression discontinuity approach to identify the boundaries of the effectiveness of SBI for students with and without MD.

Setting and Population:

Our sample of 1,492 seventh-grade students in 36 schools located in two U.S. states was taken from Jitendra, Harwell, Im, Karl, and Slater (2017b). Student and school characteristics such as the percentage of students eligible for a free/reduced price lunch, percentage of English language learners, and the percentage of Black students were generally lower than national averages (U.S. Department of Education, 2015).

Intervention:

A detailed description of SBI can be found in Jitendra et al. (2015).

Research Design and Analysis:

The multilevel model of Jitendra et al. (2017b) could be used to predict outcome values for different combinations of covariates but the many possible combinations prompted us to seek an alternative method. We employed a regression discontinuity (RD) because it provides direct information about the effectiveness of SBI and because of its ability to support strong inferences (What Works Clearinghouse, 2014). The logic of RD is typically based on the crucial role of pretests in taking student differences into account (Steiner, Cook, Shadish, & Clark, 2010), in that students with similar pretest scores can often be treated as approximately equal on background variables, enhancing causal inferences (Bloom, 2010). Similar to Jitendra et al. (2017a) GMADE pretest scores below that corresponding to the 35^{th} percentile (10 or less) led to a student being categorized as having MD and above the 35th percentile as non-MD with the GMADE posttest as the outcome; unlike Jitendra et al. (2017a) we used the PPS pretest score corresponding to the 35^{th} percentile as the MD cutoff score (9 or less) for the PPS posttest and delayed posttest outcomes and included both MD and non-MD students in the analyses. The analyses compared SBI and control students using normal-theory-based multiple regression in which pretest with a selected range of scores defined the sample and treatment (SBI = 1, Control = 0) served as a covariate, with PPS posttest, PPS delayed posttest, and the GMADE posttest serving as outcomes. Each outcome was analyzed separately using the SPSS 22.0 software package (IBM Corp., 2015).

Results:

Student and teacher demographic characteristics in the SBI and control conditions are presented in Table 1. Following the example of Robinson (2010) we conducted two-sample *t*-tests to learn whether SBI and control conditions produced similar outcomes for students with PPS and GMADE pretest scores right at the cutoff of MD status. Table 2 shows statistically significant differences between SBI and control conditions for students whose PPS pretest score was 9 or 10 on the PPS posttest ($t(252) = 5.068$, $p < .001$, $d = 0.63SD$) and delayed posttest ($t(243) = 3.340$, $p = .001$, $d = 0.43SD$) with SBI students outperforming control students. For the GMADE posttest there was a statistically significant difference between SBI and control conditions for students whose GMADE pretest score was 10 or 11 ($t(235) = 2.746$, $p = .006$, $d = 0.36SD$), with SBI students outperforming control students. These findings suggest that the impact of the treatment on all three outcomes was similar for students categorized as having (or almost having) MD.

The RD results are reported in Table 3 and Figure 1 and are based on different bandwidths of the PPS and GMADE pretests. There was a significant effect of SBI on PPS posttest and delayed posttest scores for every bandwidth studied. For example, the bandwidth of ± 1 only used students whose PPS pretest score was 8, 9, or 10 ($n = 376$) and found a significant treatment effect (slope) of 2.11 which is the estimated discontinuity. That is, for students with PPS pretest scores of 8, 9, or 10 SBI students on average scored 2.11 points higher on the PPS posttest than control students ($p < .001$, $d = 0.54SD$); in Figure 1 this is represented by the discontinuity between the two bolded lines for the PPS pretest score of 9. Similar results appeared for the GMADE posttest. The fact there were significant treatment effects for every bandwidth studied for each outcome suggests the SBI intervention is effective for a relatively broad range of proportional reasoning skills and general mathematical proficiencies.

Conclusion

Using a regression discontinuity approach provided evidence SBI is effective for a wide range of proportional reasoning skills and general mathematical proficiencies and thus broadens the population of students SBI can be used effectively with. Standardized slopes for the treatment effect also provide evidence the magnitude of the SBI effect is non-negligible, although the effect was strongest for the PPS posttest and weaker for PPS delayed posttest and the GMADE posttest.

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Table 1. *Summary of Student Demographic Information+*

		Treatment					
		SBI		Control		Total	
		n	%	*n*	%	*n*	%
Student Information							
Age	*M (SD)*	12.60	0.6	12.55	0.4	12.57	0.4
Sex	Female	268	50.5	283	48.0	551	49.2
	Male	254	47.8	300	50.9	554	49.5
Missing (age and sex)		9	1.7	6	1.0	15	1.3
Race	White	318	59.9	281	47.7	599	53.5
	Hispanic	116	21.8	196	33.3	312	27.9
	Black	49	9.2	53	9	102	9.1
	Asian	21	4	34	5.8	55	4.9
	Multiracial	18	3.4	19	3.2	37	3.3
ELL	Yes	46	8.7	69	11.7	115	10.3
	No	476	89.6	514	87.3	990	88.4
SpEd	Yes	51	9.6	59	10.0	110	9.8
	No	471	88.7	524	89.0	995	88.8
Missing		9	1.7	6	1.0	15	1.3
FRL	Yes	134	25.2	159	27.0	293	26.2
	No	33	6.2	85	14.4	118	10.5
Missing		364	68.6	345	58.6	709	63.3
Teacher Information							
Sex	Female	31	91.2	18	72.0	49	83.1
	Male	3	8.8	7	28.0	10	16.9
Math courses taken	*M (SD)*	7.53	4.8	11.12	10.3	9.05	7.7
Education courses taken	*M (SD)*	3.85	3.8	5	10.8	4.34	7.5
Years experience in math	*M (SD)*	10.76	7.0	9.84	10.5	10.4	8.6
PD hours in math	*M (SD)*	19.47	13.3	21.4	23.5	20.3	18.1

Note. + is defined by students whose GMADE pretest scores were 4-14. FRL = students eligible for free or reduced priced lunch; ELL = English language learner; SpEd = students qualified for special education services.

Table 2. *Descriptive Statistics for Outcome Variables by Treatment*

	by PPS pretest scores (= 9 or 10)						by GMADE pretest scores (= 10 or 11)					
	SBI			Control			SBI			Control		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
PPS posttest	129	14.02	4.77	125	11.22	4.02	138	14.21	5.57	104	11.49	4.55
PPS delayed posttest	124	12.86	4.64	121	10.93	4.39	129	12.94	5.21	94	10.93	4.80
GMADE posttest	128	12.32	4.11	119	11.56	3.77	137	12.91	4.18	100	11.47	3.73

Table 3. *Regression Discontinuity for the PPS and GMADE Outcome Variables*

	by Bandwidth of PPS pretest scores					by Bandwidth of GMADE pretest scores				
Outcomes	± 1 (8 ~ 10)	± 2 (7 ~ 11)	± 3 (6 ~ 12)	± 4 (5 ~ 13)	± 5 (4 ~ 14)	± 1 (9 ~ 11)	± 2 (8 ~ 12)	± 3 (7 ~ 13)	± 4 (6 ~ 14)	± 5 (5 ~ 15)
PPS posttest										
β	2.11	2.405	2.337	2.395	2.392					
Stand. β	0.225	0.246	0.238	0.240	0.233					
p	< .001	< .001	< .001	< .001	< .001					
n	376	595	760	905	1,024					
PPS delayed posttest										
β	1.165	1.054	0.986	1.099	1.106					
Stand. β	0.131	0.117	0.107	0.116	0.113					
p	0.012	0.005	0.004	0.001	< .001					
n	363	570	726	862	973					
GMADE posttest										
β						1.497	1.165	1.009	1.128	1.132
Stand. β						0.178	0.138	0.118	0.130	0.129
p						0.001	0.001	0.001	< .001	< .001
n						339	573	735	903	1,039

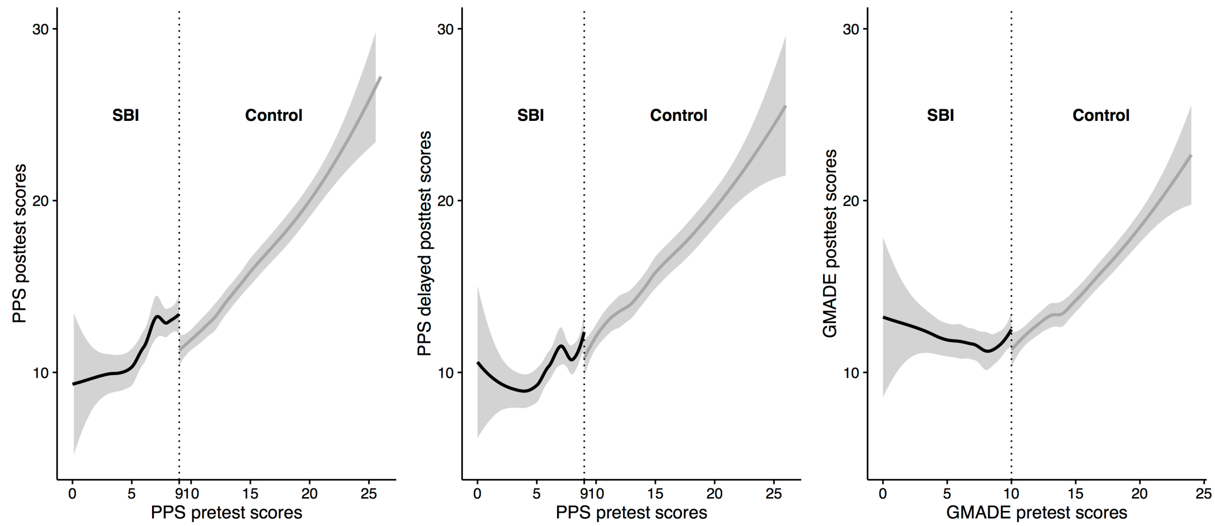

Figure 1. The effect of SBI on PPS posttest (left), delayed posttest (middle), and GMADE posttest scores (right) by PPS or GMADE pretest scores. The vertical distance between the solid lines as they approach the threshold (i.e., vertical "jump" in outcome variables) is the regression-discontinuity-based effect estimate. The gray shading represents the 95% confidence interval around the line of best fit.