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August 5, 2024 **Meta-Analysis**

EARLY IMPACT AND ESTABLISHED RESULTS: A META-ANALYSIS OF MATH NATION'S EFFECTIVENESS IN ITS INITIAL AND ONGOING USE (2022-2023)

Math is a cornerstone skill for academic success and greater opportunities in the workforce. Without successful completion of high school-level algebra, students are unlikely to be accepted into college and may be kept from entering many job training programs. Algebra 1 serves as a gateway for middle and high school students' enrollment and success in STEM related courses (Cirino et al., 2019; Torbey et al., 2020), ultimately increasing college, career, and future income opportunities (Byun, Irvin & Bell, 2015; Loveless, 2013; Gaertner et al., 2014; Kim et al., 2015; Goodman, 2019). In fact, students who complete Algebra 2 are more than twice as likely to graduate from college as students who do not complete Algebra 2 (Maltese & Tai, 2011; Powell et al., 2019).

By middle school, less than 40% of U.S. students have reached proficiency in mathematics and lack the conceptual foundations for algebraic reasoning (NCES, 2018; Loveless, 2013), and are entering algebra courses underprepared. National Assessment of Educational Progress (NAEP) results indicate that students struggle with basic algebra problems, highlighting the need for effective teaching strategies and tools to support students entering Algebra 1 underprepared (NCES, 2018). As content progresses and becomes more complex, these difficulties are compounded. Improving student knowledge and success in algebra requires finding effective pedagogical strategies, high-quality content, and innovative technologies and tools for supporting student learning, especially for those entering Algebra 1 underprepared.

Purpose/The Current Study

While existing research underscores the positive impact of Math Nation on multiple student outcomes, there remains a need to consolidate these findings to assess the program's effectiveness more comprehensively. To address this need, the current study reports results of a comprehensive meta-analysis evaluating the impact of Math Nation on student standardized test performance during the 2022-2023 school year.

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Results

A random-effects meta-analysis was conducted to synthesize the effect sizes from 13 evaluation studies (k = 13) of Math Nation. The meta-analysis was performed using the restricted maximum likelihood (REML) method. The results of the meta-analysis are summarized in Table 1.

Model Fit

The log-likelihood of the model was 7.78, and the deviance was -15.56. The Akaike Information Criterion (AIC) was -11.56, the Bayesian Information Criterion (BIC) was -10.59, and the corrected Akaike Information Criterion (AICc) was -10.23. Lower values of AIC, BIC, and AICc indicate a better fit of the model to the data, with these values suggesting that the model fits the data well.

Heterogeneity

The estimated amount of heterogeneity ($\tau^2 = 0$, SE = 0.01) was zero, and the I^2 statistic was 0.00%, indicating no substantial heterogeneity among the effect sizes. Lastly, the test for heterogeneity was not significant, $Q(12) = 5.13$, $p = 0.95$, suggesting that there was no significant heterogeneity among the effect sizes. Collectively, these results indicate that the variability in effect sizes across studies was minimal.

Effect Size

The overall effect size was statistically significant, $z = 2.28$, $p = 0.02$, with an estimated effect size of 0.10 (SE 0.04, 95% CI = 0.01, 0.19; see Figure 1). These results indicate a small but significant overall effect size, suggesting that the curriculum has a positive impact even in the earliest stages of adoption. A few studies show wide confidence intervals (see Figure 1) which could indicate higher variability or smaller sample sizes. Despite this variability, the overall effect size remains moderate and significant.

Subgroup Analyses

Subgroup analyses were conducted to explore potential variations in the effect of the Math Nation curriculum based on state and grade. Despite thorough examination, no significant differences were found between states or grades ($p > 0.05$). These results suggest that the impact of the Math Nation curriculum is consistent across different states and grade levels, aligning with the objective of

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providing a uniform benefit to all students. The lack of significant variation supports the notion that the curriculum is effective regardless of geographic or grade-level differences.

Significance

The current study aggregates evidence from multiple evaluation studies to assess the overall impact of Math Nation on student math performance. By synthesizing data across different states and educational contexts, this analysis provides a comprehensive understanding of Math Nation's effectiveness and its potential to enhance math proficiency. The findings offer valuable insights into the curriculum's generalizability, highlight areas for improvement, and inform future implementations. Additionally, the meta-analysis identifies trends and gaps that can guide the development of more targeted interventions, ultimately supporting the goal of improving math education outcomes on a broader scale.

The positive but modest overall effect size indicates that while the curriculum has a beneficial impact, further enhancements might be needed to increase its effectiveness. The consistent impact across different states and grades is encouraging and supports the curriculum's generalizability. Future research could focus on exploring specific components of the curriculum that contribute to its effectiveness and examining ways to enhance its impact. Ongoing evaluation as more data becomes available could provide deeper insights into how various factors might influence the curriculum's effectiveness, such as how the curriculum impacts different demographic groups.

Although 2023-2024 standardized test scores have not yet been released, they will be available by the April 2024 conference and will be incorporated into the meta-analysis to further enhance the findings. These new studies will provide a broader perspective and more detailed effect size comparisons. As some states are still in the early stages of implementation, initial findings show low effect sizes. We expect the program's impact to become clearer with continued use, as teachers and administrators become more confident in implementing a new program. The inclusion of these additional studies will not only strengthen the overall analysis but also help to address any potential gaps identified in the current evaluation. We anticipate that this expanded dataset will offer valuable insights and a more nuanced understanding of the Math Nation curriculum's impact across diverse contexts.

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Methods

Study Selection

This meta-analysis aimed to synthesize the efficacy of Math Nation based on evaluation studies conducted during the 2022-2023 school year. The final sample included 13 post-facto quasi-experimental design (QED) evaluation studies of Math Nation from the 2022-2023 school year. All studies included matched control groups to overcome the barriers of non-random assignment. Data were extracted from the selected studies, including sample sizes, effect sizes, and standard errors. The results of the original reports are summarized in Table 1.

Data Sources

Data for the original studies came from two sources. First, Math Nation usage data were obtained from the Math Nation analytics platform. Schools were categorized as Math Nation users if they evidence a minimum of 5 videos watched or logins per student, a threshold established in prior internal studies.

Second, demographic and performance data were retrieved from the Department of Education (DOE) websites for each state. This included school performance on math standardized tests for the 2022-2023 school year and prior year achievement data (2021-2022). Enrollment statistics, including details on race/ethnicity, economically disadvantaged students, students with individualized learning plans (IEP), and English language learners, were also collected. This dada was used for matching Math Nation and non-Math Nation schools.

Missing Data

As a measure of privacy, state data does not include a numeric value for any variable where less than 10 students contributed data. This led to missing data with variables that included fewer than 10 students not reporting numbers. To account for missing data in the covariates, the multiple imputation by chained equations (MICE) package in R (5 imputations, 20 iterations per imputation) was employed.

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Matching

To ensure comparable groups, propensity score matching was applied using the “MatchIt” package in R with Mahalanobis Distance matching. This method accounts for multiple covariates and their correlations, improving the robustness of the matching process. A multivariate distance threshold of 0.10 was set to exclude dissimilar school pairs. The matching process effectively balanced covariates across Math Nation and control groups, ensuring no significant differences in baseline math performance or other key demographic variables.

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References

Byun, S., Irvin, M., & Bell, B. A. (2015). Advanced math course taking: Effects on math achievement and college enrollment. Journal of Experimental Education, 83(4), 439-468. https:/doi.org/10.1080/00220973.2014.919570

Cirino, P.T., Tolar, T.D. & Fuchs, L.S. (2019). Longitudinal algebra prediction for early versus later takers. *The Journal of Educational Research, 112*(2), 179-191. DOI: 10.1080/00220671.2018.1486279

Collier, Z. & Leite, W. (2015). Testing the effectiveness of three-step approaches for auxiliary variables in latent class and latent profile analysis. *Structural Equation Modeling: A Multidisciplinary Journal, 24*(6), 819-830, DOI: 10.1080/10705511.2017.1365304

Dickey, E. (2018). An evaluation of Algebra Nation in South Carolina: 2017-2018. South Carolina. Education Oversight Committee. Unpublished manuscript.

Gaertner, M. N., Kim, J., DesJardins, S. L., & McClarty, K. L. (2014). Preparing students for college and careers: The causal role of algebra II. Research in Higher Education, 55(2), 143-165. https://doi.org/10.1007/s11162-013-9322-7

Leite, W. L., Cetin-Berber, D. D., Huggins-Manley, A.C., Collier, Z. K., & Beal, C.R. (2019). The relationship between Algebra Nation usage and high-stakes test performance for struggling students. *Journal of Computer Assister Learning, 35*(5). DOI: 10.1111/jcal.12360

Goodman, J. (2019). The labor of division: Returns to compulsory high school math coursework. Journal of Labora Economics, 37(4), 1141-1182. https://doi.org/10.1086/703135.

Loveless, T. (2013). The algebra imperative: Assessing algebra in a national and international context. Washington, DC: Brookings.

Maltese, A.V., & Tai, R.H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education Policy, 95*(5), https://doi.org/10.1002/sce/20441

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National Center for Education Statistics. (2018). Tables and Figures, retrieved from: https://nces.ed.gov/programs/digest/d17/tables/dt17_204.10.asp

Powell, S., Gilbert, J., & Fuchs, L. (2019). Variables influencing algebra performance: Understanding rational numbers is essential. *Learning and Individual Differences Volume (74),* 101-758.

Kim, D., Lee, Y., Leite, W. L., & Huggins-Manley, A. C. (2020). Exploring student and teacher usage patterns associated with student attrition in an open educational resource-supported online learning platform. *Computers & Education, 156,* 1-23.

Torbey, R., Martin, N.D., Warner, J.R., & Fletcher, C.L. (2020). Algebra 1 before high school as a gatekeeper to computer science participation. In Proceedings of the 51st ACM Technical Symposium on Computer Science Education, 839-844. https://doi.org/10.1145/3328778.3366877

Qiu, Y. (2018). Summary of analysis of Algebra Nation usage and Florida Algebra 1 EOC. Lastinger Center for Teaching and Learning, University of Florida, Gainesville, FL.

Qiu, Y. (2019). The effect of Algebra Nation usage on Title 1 school passing rates for the Florida Standards Assessment Algebra 1 EOC. Lastinger Center for Teaching and Learning, University of Florida, Gainesville, FL.

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Table 1. *Summary of results of included studies*

			Math Nation		Control Group					
State	**Grade**	**New/Returning User**	**Sample Size**	**Mean (SD)**	**Sample Size**	**Mean (SD)**	**Mean Difference**	**t-value**	**p-value**	**Cohen's d**
FL	6	Returning	24	60.58% (16.66%)	24	65.46% (17.67%)	-4.88%	0.98	0.33	0.28
FL	7	Returning	63	63.22% (20.22%)	63	53.76% (24.14%)	9.46%	2.39	0.02*	0.42
FL	8	Returning	25	59.08% (17.96%)	25	56.04% (20.31%)	3.04%	0.56	0.58	0.16
KY	6	New	88	38.00% (14.00%)	88	39.00% (16.00%)	1.00%	0.17	0.64	0.06
KY	7	New	101	38.58% (12.14%)	101	36.68% (12.80%)	1.90%	1.08	0.28	0.15
KY	8	New	118	37.97% (14.78%)	118	37.92% (15.02%)	0.05%	0.02	0.98	0.003
LA	8	New	52	45.88% (22.15%)	52	42.21% (20.20%)	3.67%	0.88	0.38	0.17
LA	9	New	91	62.60% (23.59%)	91	59.35% (22.93%)	3.25%	0.94	0.35	0.14
MI	11	New	99	30.17% (15.99%)	99	30.83% (16.49%)	0.66%	0.28	0.78	0.04
AL	6	New	110	26.39% (17.90%)	110	27.73% (19.17%)	0.83%	0.33	0.74	0.05
AL	7	New	98	18.96% (13.98%)	98	19.53% (16.24%)	0.57%	0.26	0.79	0.04
AL	8	New	100	18.16% (16.29%)	100	19.37% (16.14%)	-1.21%	0.54	0.59	0.08
SC	9	Returning	62	14.93% (14.13%)	62	14.26% (13.80$)	0.67%	0.27	0.79	0.05

*$p < .05$

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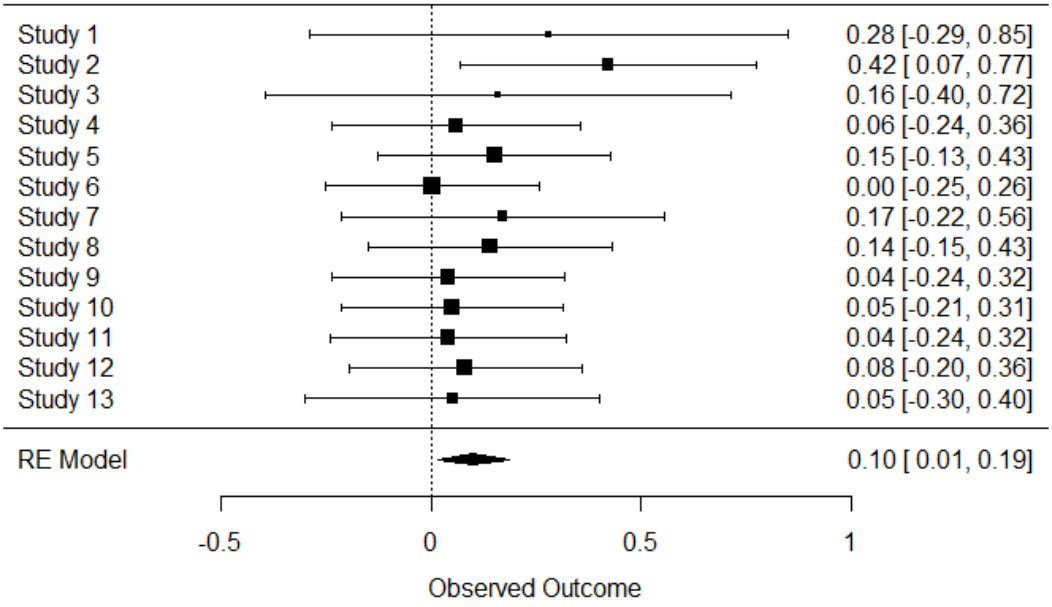

Figure 1. *Funnel plot of meta-analysis*