2016 NCTM RESEARCH CONFERENCE
April 11–13 • San Francisco

Paper Title: Exploring the Use of Mathematics Coaches and Specialists

Author(s): Harbour, K. E., Karp, K. S., & Adelson, J. A.

Session Title: Exploring the Use of Mathematics Coaches and Specialists

Session Type: Brief Research Report

Presentation Date: April 12, 2016

Presentation Location: San Francisco, California

In recent years, an emphasis on accountability and an effort to improve student performance and achievement in mathematics at the elementary school level has gained national attention (e.g., Campbell & Malkus, 2011; Hartman, 2013). With the reauthorization of the IDEA (2004), the authorization of the NCLB (2008), states, districts, schools, and teachers have felt an increased pressure to ensure that *all* students achieve at a high level (Fennell, 2006; Hartman, 2013). However, it is noted that students continue to struggle in mathematics compared to their international counterparts (IEA, 2013; NMAP, 2008). Furthermore, research indicates that students with learning disabilities and those at risk for mathematic failure continue to perform at levels below students without disabilities in measures of mathematic achievement (Judge & Watson, 2011; NAEP, 2011, 2013). In addition to these issues, research indicates that elementary school teachers often have fragmented mathematical knowledge and focus strictly on procedures as opposed to blending with conceptual understanding during instruction (e.g., Ball, 1991; Ma, 2010). Implementing the Common Core State Standards and the Mathematical Practices (CCSSI, 2014), which aim to improve the teaching and learning of mathematics, without a way to support teachers' growth in both content knowledge and pedagogical content knowledge may not produce the intended meaningful mathematics learning.

As a focus on improving elementary students' understanding and performance in mathematics is of high priority, school systems are exploring ways to support teachers and create teacher leaders who can promote high quality mathematics instruction that meets the needs of all students, incorporates the CCSSM, and supports the Standards of Mathematical Practices (Campbell & Malkus, 2011; Fennell, 2011, 2006; Polly, Mraz, & Algonzzine, 2013; Reys & Fennell, 2003). Relying on research on effective professional development (PD), which indicates that content-specific and prolonged duration of the PD provide the best avenue for impacting teacher knowledge and change (Garet, Porter, Desimone, Birman, & Yoon, 2001; Guskey, 2003; Ingvarson, Meiers, & Beavis, 2005), many districts and schools have turned to mathematics coaches and specialists (MCSs) as a catalyst for these changes (Fennell, 2006, 2011; Reys & Fennell, 2003). Based on the cognitive apprenticeship model of learning (Collins, Brown, and Newman, 1987), the current study delineates MCSs as the instructional experts that guide and support the learning of the less experienced novice (e.g., teacher or student) in a cooperative and interactive environment. Scaffolding, a structured guidance and support model (initial heavy guidance that fades to limited support), making thinking visible, and situated learning experiences characterize the foundation of cognitive apprenticeship learning model, which provides the basis for the coach-teacher, coach-student, and teacher-student relationships occurring in schools and classrooms across the country.

While serving in numerous roles, elementary MCSs have demonstrated the potential to positively influence teachers' instructional practices and beliefs in results from both qualitative and quantitative research (e.g., Baldinger, 2014; Campbell, 1996; Race, Ho, & Bower, 2002); however, some studies have noted limited changes in teachers' beliefs and practices even after the coaching process (e.g., Ai and Rivera, 2003; Olson & Barrett, 2004). MCSs have also shown to be effective on positively impacting students' mathematics learning and achievement (e.g., Balfanz, Mac Iver, & Byrnes, 2006; Campbell & Malkus, 2011). Large-scale projects focused on the relationship between MCSs and students' mathematics achievement provide evidence that these instructional leaders may provide schools the avenue needed for improved student performance (Balfanz et. al., 2006; Brosnan & Erchick, 2010; Campbell, 1996; Campbell & Malkus, 2011; Foster & Noyce, 2004). However, study limitations and the narrow number of empirical studies requires additional research to corroborate these promising findings.

Purpose and Research Questions

The purpose of the current study was to examine the relationships among elementary MCSs, fourth-grade students' mathematics achievement, and students' disability status. Additionally, the study aimed to answer the call for high-quality research by using a large-scale, nationally representative dataset along with advanced statistical analyses to provide methodologically rigorous, empirically derived evidence of the relationship between MCSs and students' mathematics achievement. Specifically, the study addressed the following research questions:

1. What is the relationship between having an elementary school-based MCS (full or part time) and fourth-grade students' achievement on the NAEP, specifically: a) their overall mathematics achievement and b) their achievement in five specific mathematics content areas (i.e., number properties and operations; measurement; geometry; data analysis, statistics, and probability; and algebra)?
2. What are the differentials in achievement of students with and without disabilities when they have an MCS in their elementary school or not?
3. For schools that have MCSs, how does principal-reported time spent on the six different roles and responsibilities (see Table 1 for a complete list) relate to students' achievement?

Methodology and Analytic Approach

This research used a quasi-experimental design (Shadish, Cook, & Campbell, 2002) with the fourth-grade mathematics survey and assessment data from the restricted-use 2011 National Assessment of Education Progress (NAEP) dataset (IRB approved). The school sample included approximately 7,490 schools, with 62% of schools reporting no MCS available and 28% of schools reporting having an MCS available (50% full-time and 50% part-time). The student sample included approximately 191,190 students with 88% of students without disabilities and 12% of students with a disability (based on IEP status). As both school and student sampling weights were incorporated into analyses to attempt to ensure that the results were representative of the targeted populations, the analytic sample size for schools included 58,685 schools (7,490 unweighted), with 68% of schools reporting no MCS and 32% of schools reporting having an MCS (49% full-time and 51% part-time). The analytic student sample size included 3,522,262 students (191,190 unweighted) with 89% of students without disabilities and 11% of students with a disability (based on IEP status). The outcome variables included a composite mathematics achievement score, in addition to five specific content area scores (i.e., number properties and operations; measurement; geometry; data analysis, statistics, and probability; and algebra). An elementary school's policy of providing a MCS served as the treatment variable and principal-reported time spent on the six specific roles and responsibilities of the MCS served as the secondary treatment variables (used for research question three).

As missing data are often problematic in large-scale datasets, multiple imputation (MI=5) was used as it allows the analyst to deal with the missing data problem in the outset and move forward with standard complete-data methods of analysis (Rubin, 1987; Schafer, 1999). This was done by using replacement values that represent a distribution of possibilities (i.e., plausible values) that were imputed for each missing piece of the data in the original dataset (excluding treatment and outcomes variables; McKnight & McKnight, 2011; Rubin, 1987). As a large number of theoretically important during-treatment covariates were identified, principal component analysis (PCA) was used to reduce the number of predictors (Stevens, 2009). The obtained composite covariates, as well as additional control variables, were then used in a series of multi-level analyses (i.e., hierarchical linear modeling; HLM) to explore the relationships between MCSs, fourth-grade students' mathematics achievement on the NAEP, and students' disability status. Because students were nested within schools in the NAEP dataset, HLM allowed for individual- and school-level variables to be appropriately modeled at different levels (level-1 and level-2, respectively).

The same general process was used for all HLM analyses (Raudenbush & Bryk, 2002). The first model was an unconditional model, which used the five plausible values for mathematics achievement as the outcome variables and included no predictor variables at level-1 or level-2. Next, individual-level predictors and covariates (student and teacher covariates) were added to create the level-1 model, followed by school-level variables to create the level-2 model. Lastly, the inclusion of the treatment variable (i.e., presence of MCS or role of MCS) created the final contextual models.

Summary of Findings

Findings indicated, on average, a statistically significant relationship between elementary schools that had full-time MCSs and fourth-grade students' overall mathematics achievement and students' achievement in five specific mathematics content areas as defined in the NAEP dataset (i.e., number properties and operations; measurement; geometry; data analysis, statistics, and probability; and algebra; see Table 2 for a summary of multi-level results). As this relationship was positive, it can be tentatively concluded that schools with full-time MCS can expect slightly higher achievement in all fourth-grade mathematics outcomes (i.e., overall or composite achievement, as well as number properties and operations, measurement, geometry, data analysis, statistics, and probability, and algebra achievement) compared to schools with no

MCSs. This positive relationship between MCSs and overall mathematics achievement echoed previous research (e.g., Campbell & Malkus, 2011; Foster & Noyce, 2004).

Interestingly, the significant relationship between full-time MCSs and mathematics achievement did not hold true when schools utilized part-time MCSs. The nonsignificant relationship between part-time MCS and achievement may suggest that as more states, districts and schools hire and rely on MCSs to be effective change agents in the teaching and learning of mathematics (Fennell, 2006, 2011; Reys & Fennell, 2003), these stakeholders should focus their resources on providing full-time MCSs to obtain the strongest relationship with higher fourth-grade mathematics achievement.

The current study found the well-known mathematics achievement gap between students with and without disabilities (Bryant et al., 2008; Judge & Watson, 2011) remains prevalent in the 2011 NAEP results for fourth-grade students. For instance, after controlling for all variables used in the final models, a student without a disability (based on IEP status) in a school with a full-time MCS can expect an average overall mathematics achievement score 20.65 points higher than a student with a disability in a school with a full-time MCS (a difference of 21.06 points between students without and with a disability occurred in schools with no MCS). This deficit for students with disabilities persisted across all five NAEP-defined mathematics content areas. Additionally, being in a school with an elementary MCS did not significantly moderate the lower achievement that students with disabilities experienced. However, it is critical to note that the overall results of the study did indicate that fourth-grade students with disabilities, as well as students without disabilities, benefited from elementary schools providing full-time MCSs (see Figure 1 for model predicted overall mathematics achievement values).

Significant relationships between principal-reported time spent on the various NAEP-defined roles and responsibilities provided by full-time MCS and achievement outcomes were noted (see Table 3), including relationships between achievement and MCSs providing assistance to both teachers and students. The most frequent MCS roles and responsibilities associated with fourth-grade students' mathematics achievement were conducting professional development for groups of teachers about mathematics content or the teaching of mathematics (i.e., Role 2), providing technical assistance/support to individual teachers about mathematics content or the teaching of mathematics (i.e., Role 1), and providing mathematics remediation/intervention to some student groups (i.e., Role 5). However, it should be noted that these measurements on the extent of time MCSs spend on each role and responsibility were not proportional in nature. This means that the extent of time spent on each role was measured independently; thus, it cannot be assumed that the measurements represented the percent of time MCSs engaged in each role. Even so, noted statistically significant relationships between principal-reported time spent on the NAEP-defined roles and achievement revealed valuable information in an area with limited research and provided information for a literature base that has an unclear definition of the effective roles and responsibilities of MCSs (e.g., McGatha, 2009; NMAP, 2008; Obara, 2010).

Statistically significant positive relationships occurred between the full-time MCSs time allocation spent working with teachers (reported by the principal or vice principal of each school) and mathematics achievement, whereas statistically significant negative relationships occurred between time allocation spent working with students and mathematics achievement. These results must be interpreted with caution as they are correlational in nature and must be interpreted while keeping the results of research question one in mind. Because research question one showed that full-time MCSs have a positive relationship with fourth-grade students' mathematics achievement, it is likely that the positive relationship between MCS Roles 1 and 2 (working with teachers) means that as MCSs spend more time working with teachers, higher mathematics achievement can be expected. In particular, Role 2 (i.e., conduct professional development for groups of teachers about mathematics content or the teaching of mathematics) appears to be the most worthwhile role in regards to working with teachers as it is significantly associated with four of the six achievement measures. In regards to working with students, full-time MCSs in schools with lower mathematics achievement are more likely to spend their time involved with providing mathematics instruction to students at various grade levels (i.e., Role 4) and providing mathematics remediation/intervention to some student groups (i.e., Role 5; see Table 3).

Conclusion

The results of this study along with previous research provide evidence of the positive influence MCSs have on elementary students' mathematics achievement. However, because this is an area with limited research, additional research is needed to establish a casual relationship between MCSs and improved mathematics performance for elementary students. Additionally, limitations to the NAEP data pertaining to MCSs posed several restrictions, such as a clear definition of "part-time" and the lack of a proportional measure of the time MCSs engage in their roles. These restrictions, among others, provide avenues for needed future research. Specifically, research to identify the most effective use of a MCSs time and how MCSs can help close the achievement gap in mathematics between students with and without disabilities should be of primary concern.

References

Ai, X. & Rivera, N. (2003). *Linking ideas to practice: Effectiveness of coaching upon teacher practice.* Paper presented at the annual meeting of the American Educational Research Association, April 23, Chicago, IL.

Baldinger, E.M. (2014). *Learning together: Looking for learning in coach-teacher interactions*. Paper presented at the National Council of Teachers of Mathematics Research Conference, New Orleans, LA.

Balfanz, R., Mac Iver, D. J., Byrnes, V. (2006). The implementation and impact of evidence-based mathematics reforms in high poverty middle schools: A multi-site, multi-year study. *Journal for Research in Mathematics Education, 37,* 33-64.

Ball, D.L. (1991) Research on teaching mathematics: Making subject matter knowledge part of the equation. Retrieved from: http://www.teoeducation.com/teophotos/albums/userpics/10_1_1_118_4400.pdf.

Brosnan, P. & Erchick, D. (2010). *Mathematics coaching and its impact on student achievement.* Paper presented in P. Brosnan, D. B. Erchick, & L. Flevares (Eds.) Proceedings of the 32nd annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (Volume VI, p. 1362-1370). Columbus, OH: The Ohio State University.

Bryant, B. R., Bryant, D. P., Kethley, C., Kim, S. A., Pool, C., & Seo, Y. J. (2008). Preventing mathematics difficulties in the primary grades: The critical features of instruction in textbooks as part of the equation. *Learning Disability Quarterly*, *31,* 21-35.

Campbell, P. F. (1996). Empowering children and teachers in the elementary mathematics classrooms of urban schools. *Urban Education*, *30,* 449–475.

Campbell, P. F., & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal*, *111*, 430-454.

Collins, A., Brown, J. S., & Newman, S. E. (1987). *Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics* (Technical Report No. 403). Washington, DC: National Institute of Education. Retrieved from http://files.eric.ed.gov/fulltext/ED284181.pdf.

Common Core State Standards Initiative. (2014). *Common core state standards initiative: Preparing America's students for college and careers.* Retrieved from http://www.corestandards.org/.

Fennell, F. (2006). We need elementary school mathematics specialists now. *NCTM News Bulletin*, *43*(4).

Fennell, F. (2011). We need elementary mathematics specialists now, more than ever: A historical perspective and call to action. *NCSM Journal, Summer/Fall*, 53-60.

Foster, D. & Noyce, P. (2004). The mathematics assessment collaborative: Performance testing to improve instruction. *Phi Delta Kappan, 85,* 367-374.

Garet, M.S., Porter, A.C., Desimone, L., Birman, B.F.& Yoon, K.S. (2001). What Makes Professional Development Effective? Results From a National Sample of Teachers. *American Educational Research Journal*, *38*(4), 915-945.

Guskey, T.R. (2003). What Makes Professional Development Effective? *Phi Delta Kappan, 84*(10), 748-750.

Hartman, S. (2013). Math coaching in a rural school: Gaining entry: A vital first step. *Journal of Education*, *193*, 57-67.

Individuals With Disabilities Education Act, 20 United States Code (U.S.C.) § 1400 (2004).

Ingvarson, L., Meiers, M. & Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practice, student outcomes & efficacy. Education Policy Analysis Archives, *13*(10), 1-26.

International Association for the Evaluation of Educational Achievement. (2013). *Trends in international mathematics and science study, TIMSS, 2011*. Retrieved from http://timss.bc.edu/timss2011/.

Judge, S., & Watson, S. M. (2011). Longitudinal outcomes for mathematics achievement for students with learning disabilities. *The Journal of Educational Research*, *104*, 147-157.

Ma, L. (2010). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States* (2nd ed.). New York: Routledge.

McGatha, M. (2009). Mathematics Specialists and Mathematics Coaches: What Does the Research Say?. *NCTM Research Briefs*.

McKnight, P.E. & McKnight, K.M. (2011). Missing data in secondary data analysis. In K. H. Trzesniewski, M. B. Donnellan, & R. E. Lucas (Eds.), *Secondary data analysis: An introduction for psychologists* (p. 83-101). Washington, DC: American Psychological Association.

National Assessment for Educational Progress. (2013). *The Nation's report card.* National Center of Education Statistics, Institute of Education Sciences. Retrieved from http://www.nationsreportcard.gov/.

National Center for Education Statistics (2011). *The Nation's Report Card: Mathematics 2011* (NCES 2012-458). Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

National Mathematics Advisory Panel. (2008). Foundations for success: The final report of the national mathematics advisory panel. Washington, DC: U.S. Department of Education.

No Child Left Behind Act of 2001, Pub. L. No. 107-110, 20 U.S.C. 6301 (2002).

Obara, S. (2010). Mathematics coaching: A new kind of professional development. *Teacher Development, 14,* 241–251.

Olson, J. C., & Barrett, J. E. (2004). Coaching teachers to implement mathematics reform recommendations. *Mathematics Teacher Education and Development, 6,* 63–78.

Polly, D., Mraz, M., & Algozzine, R. (2013). Implications for developing and researching elementary school mathematics coaches. *School Science and Mathematics, 113,* 297-307.

Race, K., Ho, E., & Bower, L. (2002, April 1-5). *Documenting in-classroom support and coaching activities of a professional development program directed toward school-wide change: An integral part of an organization's evaluation efforts.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Raudenbush, S., & Bryk, A. (2002). *Hierarchical linear models (2nd ed.).* Newbury Park, CA: Sage.

Reys, B. J. & Fennell, F. (2003). Who should lead mathematics instruction at the elementary school level? A case for mathematics specialists. *Teaching Children Mathematics, 9,* 277-282.

Rubin, D. B. (1987). *Multiple imputation for nonresponse in surveys*. New York, NY: John Wiley & Sons, Inc.

Schafer, J. L. (1999). Multiple imputation: A primer. *Statistical Methods in Medical Research*, *8*, 3-15.

Shadish, W.R., Cook, T.D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference.* New York: Houghton Mifflin.

Stevens, J. P. (2009). *Applied multivariate statistics for the social sciences (5th ed.).* New York, NY: Routledge.

Table 1

Roles and Responsibilities of Mathematics Coach/Specialist as defined in the 2011 NAEP dataset

	Roles and Responsibilities of MCSs
1)	Provide technical assistance/support to individual teachers about mathematics content or the teaching of mathematics
2)	Conduct professional development for groups of teachers about mathematics content or the teaching of mathematics
3)	Provide mathematics instruction to students on various topics
4)	Provide mathematics instruction to students at various grade levels
5)	Provide mathematics remediation/intervention to some student groups
6)	Provide mathematics enrichment to some student groups

Table 2

Final Multi-level Models Examining the Relationship between a School's Policy of Providing a Full-Time or Part-Time Mathematics Coach/Specialist (MCS) and Students' Mathematics Achievement based on Disability Status

	Composite	Number & Op	Measurement	Geometry	Data & Prob	Algebra
Fixed Effects	Coefficient (*SE*)	Coefficient (*SE*)	Coefficient (*SE*)	Coefficient (*SE*)	Coefficient (*SE*)	Coefficient (*SE*)
Model for intercept math ach. ($\square_{0}$)						
Intercept ($\square_{00}$)	246.33*	245.29*	246.33*	244.53*	248.12*	249.65*
	(0.21)	(0.26)	(0.28)	(0.26)	(0.32)	(0.24)
Full-time MCS ($\square_{07}$)	1.69*	1.66*	1.75*	1.40*	2.07*	1.89*
	(0.35)	(0.46)	(0.44)	(0.47)	(0.41)	(0.42)
Part-time MCS ($\square_{08}$)	0.16	0.18	-0.39	0.20	0.81	0.31
	(0.34)	(0.40)	(0.48)	(0.40)	(0.54)	(0.34)
Model for IEP slope ($\square_{15}$)						
Intercept ($\square_{150}$)	-21.06*	-23.06*	-23.59*	-15.21*	-18.93*	-19.51*
	(0.30)	(0.41)	(0.52)	(0.37)	(0.36)	(0.43)
Full-time MCS ($\square_{151}$)	0.41	-0.07	0.86	0.35	0.64	0.94
	(0.62)	(0.71)	(0.74)	(0.65)	(0.82)	(0.59)
Part-time MCS ($\square_{152}$)	0.45	0.15	1.09	0.78	0.67	0.66
	(0.63)	(0.73)	(0.81)	(0.72)	(0.76)	(0.59)

*$p < .05$

Note. The shown models are the final contextual models with all composite covariates and controls included.

Table 3

Statistically Significant Relationships between Principal-reported Time Spent on the NAEP-defined Mathematics Coaches/Specialists (MCS) Roles and Responsibilities and Fourth-Grade Students' Mathematics Achievement

MCS roles working with TEACHERS	MCS roles working with STUDENTS
Provide technical assistance/support to individual teachers about mathematics content or the teaching of mathematics (Role 1)[C, M,G]	Provide mathematics instruction to students at various grade levels (Role 4)[D, A]
Conduct professional development for groups of teachers about mathematics content or the teaching of mathematics (Role 2)[C, N, M, D]	Provide mathematics remediation/intervention to some student groups (Role 5)[C, D, A]
*Both positive relationships	*Both negative relationships

[C] composite (i.e., overall)
[N] number properties and operations
[M] measurement
[G] geometry
[D] data analysis, statistics, and probability
[A] algebra

Note. Roles 3 and 6 did not have statistically significant relationships with mathematics achievement.

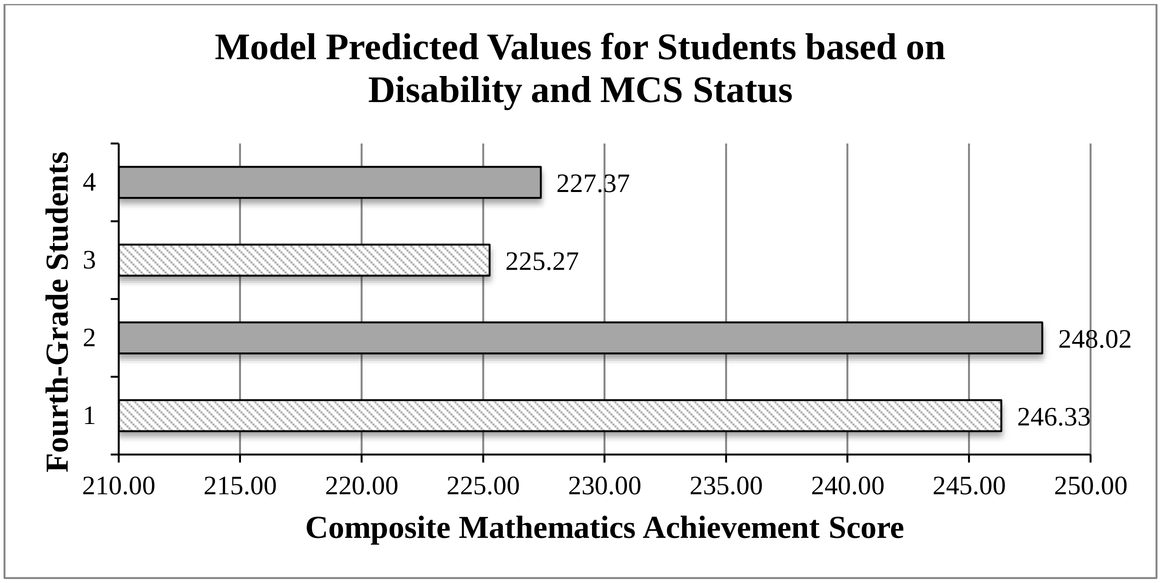

Figure 1. Model Predicted Values for Composite Mathematics Achievement Scores for Fourth-Grade Students based on Disability and MCS Status.
[1] Student without a disability in a school with no MCS. [2] Student without a disability in a school with a full-time MCS. [3] Student with a disability in a school with no MCS. [4] Student with a disability in a school with a full-time MCS