A Pilot Study of the Effects of Mathematics Leadership Corps on Teacher Leadership Development and Instructional Practice

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Abstract

This study examines the effects of Mathematics Leadership Corps (MLC), a mathematics teacher leadership development model that emphasizes shared leadership and continuous professional development to improve student learning, on teacher leadership and instructional practice within a K-12 school district. Two cohorts of K-12 teachers (n=47) participated in MLC for two years. The results from teacher questionnaires and classroom observations suggest that MLC has a positive effect on the perception of teacher leadership within their school and district among early adopters, but not for later adopters. The results also suggest that differing exposure to MLC may have an effect on teachers' instructional practice. While both early adopters and later adopters improved quality of data-driven math instruction over time, early adopters' instructional practice was rated higher than their counterparts' instructional practice due to gains made in their first year of participation in MLC. Implications for school-wide and district-wide organizational change will be discussed.

Background and Purpose

Studies consistently note that an achievement gap in mathematics exists between ethnic groups and between socioeconomically disadvantaged and non-disadvantaged students. For instance, the 2013 National Assessment of Educational Progress (NAEP) results show that in California, while 42% of White students scored proficient or above in math, only 15% of Latino and 11% of African-American students met the scores for proficiency (National Center for Education Statistics, n.d.). While research attributes this achievement gap in mathematics to several factors including unequal access to high quality teachers, schools, and resources (Flores, 2007), data reveal that the gap exists even within the same school or district (Balfanz & Byrnes, 2006). Closing this gap by creating equitable conditions for all students within the school or district is vital for strengthening and sustaining democracy (Krovetz & Arriaza, 2006).

Teacher leadership may be key to improving student learning for all, and narrowing the achievement gap. Research indicates that teachers participating in leadership learn to successfully manage challenging issues such as equity (Lambert, 2003). When these teacher leaders share their learning experiences with their colleagues, the impact of their leadership can reach more students. The literature goes on to state that a school utilizing the leadership skills and different expertise of multiple teachers can be more effective in educating students than a school relying on a single leader (Krovetz & Arriaza, 2006). Moreover, when teachers collaborate to make decisions regarding curriculum, instructional methods, and professional development, students have higher achievement in mathematics (Goddard, Goddard, & Tschannen-Moran, 2007).

In order for teacher leadership to truly impact student achievement in mathematics, teachers' leadership development and instructional improvement need to co-occur. Teacher leadership is historically grounded in school improvement efforts and therefore requires greater professionalization (Anderson, 2004). When all educators within the school recognize that improving instruction to increase student learning is a shared responsibility, continuous professional learning becomes inherent in the school's culture (Johnson & Uline, 2005). Such transformation of a school's or district's learning culture is impossible without the support of leadership at all levels, including both teachers and administrators (Harris & Muijs, 2004; Stoll et al., 2006). Therefore, shared leadership between teachers and administrators may be key to such organizational change in the learning culture (Harris & Muijs, 2004).

Research indicates that teachers learn substantially from direct observation of their peers' professional practices (Reeves, 2008). Peer instructional coaching has gained attention as a form of leadership that influences teachers' professional learning, instructional practices, and leadership skills (Charteris & Smardon, 2014; Knight, 2009). Despite instructional coaches' potential role in creating district-wide change through professional development (Gallucci, Van Lare, Yoon, & Boatright, 2010), rigorous research on instructional coaching as it relates to teacher leadership is lacking (Cornett & Knight, 2009). Moreover, a gap exists in the literature on networks of instructional coaches as agents of organizational change at the school and district levels. The purpose of this study is to examine the effects of a mathematics teacher leadership model on (a) teacher perception of teacher leadership and (b) implementation of effective instructional practices within a K-12 school district.

Mathematics Teacher Leadership Model

The Mathematics Leadership Corps (MLC) is a teacher leadership model that identifies and develops teacher leaders by partnering with K-12 school districts to provide research-informed professional development for math teachers. Implemented over a three-year span, MLC trains K-12 math teachers to coach their peers for data-driven instruction and create a culture of shared leadership and continuous improvement within the district. Activities for teachers include one-on-one and team coaching, team coaching seminars, lesson co-planning, and observation of exemplary math instruction by peers and experts.

MLC Data-Driven Instructional Practice

MLC provides distinct professional development programs for elementary and secondary schools to increase teachers' knowledge and skills to deliver data-driven mathematics instruction. The professional development program for elementary schools is the Art of Teaching program delivered by the Cotsen Foundation. It focuses on Cognitively Guided Instruction (CGI), an inquiry based instructional approach that emphasizes students' articulation of their mathematical thinking during problem solving, and teachers' utilization of that information to deepen students' conceptual understanding (Carpenter, Fennema, Franke, Levi, & Empson, 2015). In each elementary school, a team of one full-time coach and up to seven teachers participate in the program. Each participating teacher sets his/her own goals for teaching and student learning, resulting in unique, customized professional development for each teacher. The professional development program for secondary schools is the Math Leadership and Learning Design (MLD) program implemented by Loyola Marymount University. MLD teachers support students in improving their problem solving skills by analyzing the problem, making a plan, monitoring their understanding and actions, and engaging in metacognition (Pólya, 1945; Schoenfeld, 1985; Schoenfeld, 1987). The program uses experiential learning to help teachers interpret student data, identify instructional practices in response to the data, and engage in collaborative problem solving. Each secondary school has varying numbers of coaches depending on the school's need and coach availability. Each coach, who still teaches in the classroom, partners with two to three teachers to participate in one-on-one peer coaching.

Common key components of the elementary and secondary programs are one-on-one peer coaching and group collaborations. Coaches receive training in coaching and work with each of their participating teachers weekly in classrooms or individual planning sessions. The coach and teacher dyad analyzes and interprets student data, reflects on teacher's instructional practice, and plans further learning for the teacher. Participating coaches and teachers also meet in groups to analyze student data, design instruction accordingly, and address a school-wide problem of practice.

Teacher Leadership

The MLC model (Figure 1) includes different levels of leadership that influence each other and ultimately student learning in mathematics. Teacher leadership within the school and district continues to grow through the reciprocal relationships among teachers, administrators, and students. The MLC model leadership domains are: a) *shared leadership* in which teachers and administrators work together to make research informed decisions about teaching and learning such as curriculum and professional development. Teachers and administrators sustain this culture of shared leadership through enacting *shared vision* and *collaboration*. b) *continuous improvement*, a culture of frequent and focused review of real-time instructional practice. Teacher and administrators foster this culture through one-on-one partnership coaching that focused on data-driven instruction; and c) *student-led learning* in which teacher leadership and consistent implementation of MLC instructional practices promote self-regulated learning. While student-led learning is an important element of the MLC model, this paper focuses on teacher leadership including shared leadership and continuous improvement.

The MLC model places teachers at the center of organizational change and growth by taking a democratic approach where individuals can freely express their ideas (Harris & Muijs, 2004). Prior to implementation in each district, teachers and administrators actively participate in deciding how to implement MLC. The driver of the MLC model is continuous improvement. Integral to a school's capacity to continuously improve instruction and students' mathematical problem solving expertise is the purposeful, strategic use of student data. The challenge however, for most educators is determining how to collect what kind of data, and how to interpret those. A critical role of the coaches is help to assist teachers in identifying, collecting, and analyzing data, and translating the results into teaching that supports improvement in the problem solving abilities of their students. MLC's role is to help administrators realize that continuous improvement is essential for improvement in student learning, and put an effective coaching system in place in their schools that supports the improvement process. Once the district establishes this coaching system, teachers learn to collaborate more effectively through one-on-one relationships as well as in small groups because they have a common language and the common ground of data analysis. Then leadership becomes distributed as coaches work with both teachers and administrators, thereby encouraging teachers to work in partnership. As a result, shared leadership evolves gradually in the district. Finally, as teachers work on improving their instruction through coaching for data-driven instruction, they influence student learning and ultimately foster student-led learning where students become problem solving experts.

Theoretical Framework

This study uses the diffusion of innovations theory (Rogers, 2003) to describe how MLC develops teacher leadership within a school district for sustainable organizational change. The theory defines an innovation as an idea or practice that individuals or social systems perceive as new. While MLC itself is a new program to teachers at first, it also brings a new idea that anyone can be a leader who creates changes in the culture of learning and collaboration within the district. Within organizations, an innovation progresses through five steps (Rogers, 2003). First, agenda setting occurs when an organizational problem triggers the identification of a perceived need. Subsequently, an innovation that fits the need is planned and designed. MLC’s involvement in a district is initiated at this level as an innovation to potentially address the organization’s instructional problem of practice. The next step is redefining/restructuring, during which the innovation is redesigned to accommodate the specific needs and structure of the organization. As previously mentioned, teachers and administrators actively participate in this process of customizing MLC for their district. Next, as the innovation gradually spreads within the organization, members clarify the meaning of the innovation. Lastly, routinization indicates that the innovation has become fully incorporated into the regular activities of the organization and continues to be used. MLC's ultimate goal is to routinize shared leadership, teacher-led learning and collaboration as a culture within the school district. This routinization, in turn, is expected to have continued impact on student learning and narrowing of the achievement gap in mathematics through effective and personalized instruction for each student.

Methods

Site

MLC was implemented in a mid-sized, urban, ethnically diverse K-12 school district in California beginning in the 2013-14 academic year. In 2013-14, over 6,500 students attended 5 elementary schools, 1 middle school, 1 high school, and 1 continuation school within the district. Table 1 shows the demographic and math performance data of the student body.

Design

This quasi-experimental design used a modified version of the nonequivalent control group design with switching replications (Shadish, Cook, & Campbell, 2002):

		2013-14		2014-15	
Initial treatment (IT)	O_1	X	O_2	X	O_3
Delayed treatment (DT)	O_1		O_2	X	O_3

Teachers at the school district were invited to participate in MLC initially in the 2013-14 academic year. Those who chose to participate formed an initial treatment group (IT) and filled out a baseline survey (O_1) prior to the implementation of MLC. The rest of the teachers were also asked to participate in the baseline survey (O_1) to serve as a control group. These teachers were provided the opportunity to join MLC in the 2014-15 academic year to form a delayed-treatment group (DT). In a typical switching replications design, the IT group becomes a control group in the second phase. However, in this study, the IT group continued to receive the treatment as MLC is designed to provide two years of intensive coaching and an additional year of support. At the end of each academic year, the two groups filled out a mid-survey (O_2) and a post-survey (O_3). The IT group's classrooms were observed in all three data collection time points (O_1, O_2, and O_3), while the DT group's classrooms were observed in O_2 and O_3 only.

Sample

Initially, the IT group included 16 teachers from two elementary schools, one middle school, and one high school. The DT group included 31 teachers from two other elementary schools and the middle and high schools. Table 2 shows the demographic information of the sample. Over time, sample attrition occurred due to staff turnover and leave of absence. The DT group also had smaller number of participants who took the baseline survey. Therefore, the analysis sample was smaller. For the teacher survey, the analysis sample included 13 IT participants and 8 DT participants who had taken both baseline (O_1) and post-survey (O_3). For the classroom observations, the analysis sample included 14 IT participants and 22 DT participants who had observation data at both O_2 and O_3.

Measures

Teacher questionnaire. This study used a questionnaire developed for evaluating the MLC model. Analysis used 27 items that measure three distinct domains of teacher leadership outlined in the MLC model: Shared Vision, Collaboration, and Continuous Improvement. Shared Vision and Collaboration make up Shared Leadership. The items measured teachers' perception of teacher leadership in their schools on a five-point scale from *not true* to *definitely true*, for example: “Teacher leadership is shared according to expertise rather than seniority.” Cronbach’s alpha for the subscales ranged from .92 to .96.

Classroom observation. Trained field observers visited MLC participant teachers’ math classrooms at baseline and at the end of each academic year. Two observers were in one classroom at a time. One observer rated teachers’ use of MLC data-driven instructional practices using a 27-item instrument developed by the researchers. The other observer rated students’ engagement in math which is not part of this paper. Teacher observation items were categorized according to the eight Standards for Mathematical Practice outlined in National Council of Teachers of Mathematics (2014). For example, “Allows students to figure out problems before giving the answer” was part of a subscale measuring “Support productive struggle in learning mathematics.”

Procedures

The Institutional Review Board at Loyola Marymount University approved the study procedures. At each data collection time point, the participants received an email invitation to fill out the questionnaire online through SurveyGizmo (www.surveygizmo.com). A project coordinator contacted the participants to schedule observations. Each participant selected a class period to be observed.

Analysis

The researchers created composite scores for each domain of teacher leadership and instructional practice by computing the mean of all non-missing items within the domain. Analysis methods included descriptive statistics, parametric and nonparametric bivariate analyses, and repeated measures mixed models. Teacher leadership analysis included baseline (O_1) and post-test (O_3) survey responses. Since DT group did not participate in classroom observation at baseline, instructional practice analysis used mid-test (O_2) and post-test (O_3) observation scores.

Results

Table 3 presents the descriptive results of the teacher questionnaire and classroom observations for each time point. IT group's mean teacher leadership score increased significantly from baseline to post-test, $t(12)=-3.04$, $p<.05$. Their mean MLC data-driven instructional practice score increased significantly from mid-test to post-test, $z=-2.86$, $p<.01$. DT group's overall means did not change significantly over time. However, their use of two specific MLC data-driven instructional practices, posing purposeful questions and building procedural fluency from conceptual understanding, increased from mid-test to post-test.

Table 4 displays multilevel mixed-effects regression analysis results for teacher leadership and use of MLC data-driven instructional practices. As shown in Figure 2, IT group's perception of teacher leadership increased over time. DT group started with a higher mean score than IT group at baseline, but their perception of teacher leadership non-significantly decreased over time. Figure 3 shows that both groups' instructional practice scores increased from mid-test to post-test, but IT group's mean scores at both time points were higher than DT group's scores in the second year of MLC implementation.

Discussion

The results suggest that MLC has a positive effect on the perception of teacher leadership among early adopters, but for others it may raise awareness of shortcomings in teacher leadership within their school or district. Because MLC is designed to have teachers self-select into the program, the IT group may have included teachers who were motivated due to perceived lack of teacher leadership in their schools. Then through participation in MLC, IT teachers worked closely with their coaching partners, which may have contributed to the increase in their perception of teacher leadership. This is consistent with literature that links instructional coaching and leadership (Charteris & Smardon, 2014; March et al., 2010; Roehrig et al., 2008). In contrast, the DT group may have realized over the course of their participation in the second year that teacher leadership at their schools still needs to grow. Alternatively, the district may be at a stage in the diffusion of innovations where later adopters are still trying to understand the meaning of the MLC model. According to the theory, organizations re-invent the innovation to accommodate their needs and also modify their organizational structure to fit with the innovation (Rogers, 2003). Since IT group was more involved in this process due to their earlier participation in the program, they may have had more chance to work together and share leadership with other formal and informal leaders in their schools, thereby increasing their perception of teacher leadership. On the other hand, DT group had fewer opportunities to participate in the restructuring process and may have developed a different view on shared leadership.

While both groups increased their use of MLC data-driven instructional practices in the second year, IT group overall scored higher than DT group. This suggests that differing exposure to MLC may have an effect on data-driven instructional practice. Descriptive statistics show that IT group's instructional practice improved steadily from baseline to mid-test to post-test, indicating that gains made in the first year placed IT group's mean score above the DT group's mean in their initial year of participation. One possible explanation for this finding is that in the second year, new coaches started coaching while learning the instructional methods side-by-side with the teachers. This is an important feature of the MLC program based on research that coaches who are embedded within the school system can provide ongoing training and support for data-driven instruction (O’Connor & Freeman, 2012). Future research should further examine its effects on student engagement and achievement in math.

This study contributes to the literature on teacher leadership for organizational change by describing how a long-term leadership and professional development program influences teachers at all grade levels. A main limitation of the study is small, non-random sample which limits the generalizability of the findings to other districts. Moreover, this study used data collected in two-year span which may not be long enough to observe changes in perceptions of organizational culture such as shared leadership. The difference in perception of shared leadership between IT group and DT group needs further exploration. Similarly, observation data for instructional practices were limited to one period at beginning and end of one academic year, which may not be enough to capture all instructional practices that teachers may implement in their classroom. Further evaluation of MLC in multiple sites over time will generate recommendations for schools and districts that seek to improve their learning culture, teacher leadership, data-driven instructional practice, and student achievement.

REFERENCES

Anderson, K. D. (2004). The nature of teacher leadership in schools as reciprocal influences between teacher leaders and principals. *School Effectiveness and School Improvement, 15*(1), 97-113.

Balfanz, R. & Byrnes, V. (2006). Closing the mathematics achievement gap in high-poverty middle schools: enablers and constraints. *Journal of Education for Students Placed at Risk, 11* (2), 143-159.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (2015). *Children's Mathematics*. Portsmouth, NH: Heinemann.

Charteris, J., & Smardon, D. (2014). Dialogic peer coaching as teacher leadership for professional inquiry. *International Journal of Mentoring and Coaching in Education, 3*(2), 108-124.

Cornett, J., & Knight, J. (2009). Research on coaching. In J. Knight (Ed.), *Coaching Approaches and Perspectives* (pp. 192-216). Thousand Oaks, CA: Corwin Press.

Ed-Data. (n.d.) *District Summary*. Retrieved from http://www.ed-data.org

Flores, A. (2007). Examining disparities in mathematics education: Achievement gap or opportunity gap? *The High School Journal*, *91*(1), 29-42.

Gallucci, C., Van Lare, M. D., Yoon, I. H., & Boatright, B. (2010). Instructional coaching building theory about the role and organizational support for professional learning. *American Educational Research Journal, 47*(4), 919-963.

Goddard, Y., Goddard, R., & Tschannen-Moran, M. (2007). A theoretical and empirical investigation of teacher collaboration for school improvement and student achievement in public elementary schools. *The Teachers College Record*, *109*(4), 877-896.

Harris, A., & Muijs, D. (2004). *Improving schools through teacher leadership*. England: McGraw-Hill Education.

Johnson, Jr, J. F., & Uline, C. L. (2005). Preparing educational leaders to close achievement gaps. *Theory into practice, 44*(1), 45-52.

Knight, J. (2009). Coaching: the key to translating research into practice lies in continuous, job-embedded learning with ongoing support. *JSD: The Learning Forward Journal, 30*, 18-22.

Krovetz, M. L., & Arriaza, G. (Eds.). (2006). *Collaborative teacher leadership: How teachers can foster equitable schools*. Thousand Oaks, CA: Corwin Press.

Lambert, L. (2003). *Leadership capacity for lasting school improvement*. Alexandria, VA: Association for Supervision and Curriculum Development.

Marsh, J. A., McCombs, J. S., & Martorell, F. (2010). How instructional coaches support data-driven decision making. *Educational Policy*, *24*(6), 872-907. doi:10.1177/0895904809341467

National Center for Education Statistics. (n.d.). *2013 Mathematics assessment report card: summary data tables with additional detail for average scores and achievement levels for states and jurisdictions.* Retrieved from http://www.nationsreportcard.gov/ reading_math_2013/files/Results_Appendix_Math.pdf

National Council of Teachers of Mathematics (NCTM). (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: Author.

O'Connor, E. P., & Freeman, E. W. (2012). District-level considerations in supporting and sustaining RtI implementation. *Psychology in the Schools*, *49*(3), 297-310. doi:10.1002/pits.21598

Pólya, G. (1962). *Mathematical Discovery*. New York: Wiley

Reeves, D. B. (2008). *Reframing teacher leadership to improve your school*. Alexandria, VA: Association for Supervision and Curriculum Development.

Roehrig, A. D., Duggar, S. W., Moats, L., Glover, M., & Mincey, B. (2008). When teachers work to use progress monitoring data to inform literacy instruction. *Remedial and Special Education*, *29*(6), 364-382. doi:10.1177/0741932507314021

Rogers, E. M. (2003). *Diffusion of innovations*. New York, NY: Simon and Schuster

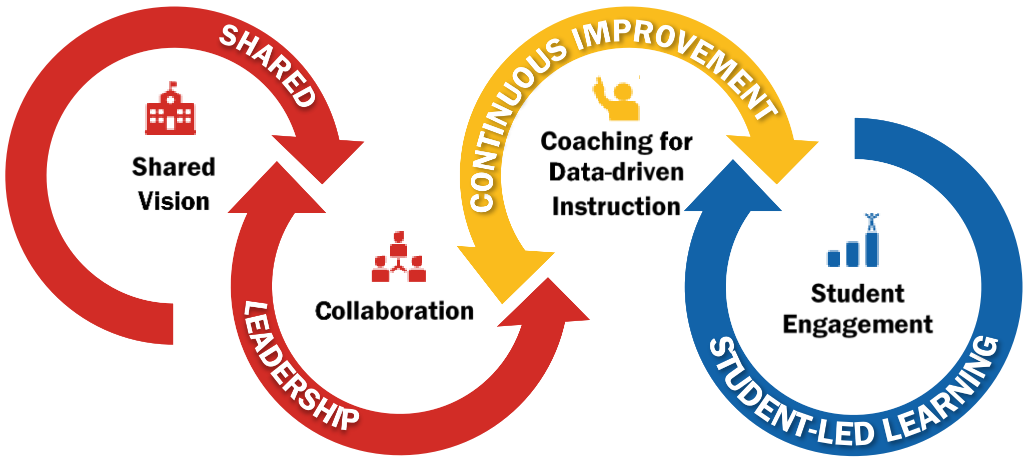
Schoenfeld, A. H. (1985). *Mathematical problem solving*. Orlando, FL: Academic Press

Schoenfeld, A. H. (1987). What's All The Fuss About Metacognition?. In A. H. Schoenfeld (Ed.), *Cognitive Science and Mathematics Education* (pp. 189-215). Schoenfeld. Hillsdale, NJ: Lawrence Erlbaum Associates

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

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: a review of the literature. *Journal of Educational Change*, *7*, 221-258. DOI: 10.1007/s10833-006-0001-8

Figure 1. Mathematics Leadership Corps (MLC) Leadership Model



Note: Icons made by Freepik from www.flaticon.com

Table 1. District demographic and math performance data, 2013-14 academic year

Demographics	District %	State %	Math proficient or above in state standardized test	District %	State %
Race/ethnicity			Overall	74%	60%
Latino/a	40%	53%	Latino/a	66%	51%
White	26%	25%	White	83%	71%
African American	16%	6%	African American	64%	42%
Asian/Pacific Islander	13%	11%	Asian	92%	85%
Eligible for free and reduced price lunch	39%	59%	Eligible for free and reduced price lunch	64%	50%
English Learner	12%	23%	English learner	64%	49%

Source: Ed-Data. (n.d.) *District Summary*. Retrieved from http://www.ed-data.org

Table 2. Demographic information of the sample at baseline (n=47)

Demographics	**Initial treatment group** (n=16)		**Delayed treatment group** (n=31)		**Combined** (n=47)	
	Freq.	%	Freq.	%	Freq.	%
Gender						
Female	13	81 %	25	81 %	38	81 %
Male	3	19 %	6	19 %	9	19 %
Race/Ethnicity						
White	10	63 %	17	55 %	27	57 %
African American	1	6 %	1	3 %	2	4 %
Latino/a	2	13 %	5	16 %	7	15 %
Asian	3	19 %	6	19 %	9	19 %
Other	0	0 %	2	6 %	2	4 %
Credential						
Multiple subjects	8	50 %	12	40 %	20	43 %
Single subject foundational mathematics	2	13 %	9	30 %	11	24 %
Single subject mathematics	2	13 %	6	20 %	8	17 %
Other	4	24 %	3	10 %	7	15 %
Type of credential						
Preliminary	0	0 %	5	17 %	5	11 %
Professional Clear	16	100 %	25	83 %	41	89 %
Years of teaching experience						
1-5 years	3	19 %	4	50 %	7	29 %
6-10 years	3	19 %	2	25 %	5	21 %
11-15 years	3	19 %	1	13 %	4	17 %
16-20 years	2	13 %	0	0 %	2	8 %
21-25 years	2	13 %	1	13 %	3	13 %
More than 25 years	3	19 %	0	0 %	3	13 %

Table 3. Changes in teacher leadership and instructional practice

Domains		Baseline M (SD)	Mid-test M (SD)	Post-test M (SD)	Change from baseline to post-test [a]
Self-Reported Teacher Leadership					
Shared Vision	IT	2.69 (1.05)	3.60 (1.05)	3.72 (0.47)	p=.004
	DT	3.84 (0.73)	3.48 (1.01)	3.24 (1.09)	n/s
Collaboration	IT	2.56 (0.89)	3.79 (1.14)	3.42 (1.27)	p=.014
	DT	3.70 (1.20)	3.80 (1.28)	2.64 (1.36)	n/s
Continuous Improvement	IT	2.97 (0.93)	3.48 (1.18)	3.60 (0.76)	p=.026
	DT	3.83 (0.78)	3.67 (0.91)	3.50 (0.86)	n/s
All domains combined	IT	2.81 (0.83)	4.13 (0.61)	3.60 (0.50)	p=.010
	DT	3.80 (0.76)	3.94 (0.69)	3.25 (0.93)	n/s

Domains		Baseline M (SD)	Mid-test M (SD)	Post-test M (SD)	Change from mid-test to post-test [b]
Observed Use of MLC Data-Driven Instructional Practice					
Establish mathematics goals to focus learning	IT	3.02 (0.59)	3.49 (0.36)	3.83 (0.54)	p=.018
	DT	N/A	2.69 (0.44)	2.86 (1.15)	n/s
Implement tasks that promote reasoning and problem solving	IT	2.00 (0.76)	3.39 (0.45)	3.65 (0.66)	n/s
	DT	N/A	2.59 (0.46)	2.92 (1.12)	n/s
Use and connect math representations	IT	2.89 (0.56)	3.55 (0.46)	4.18 (0.62)	p=.002
	DT	N/A	2.89 (0.45)	3.17 (1.14)	n/s
Facilitate meaningful mathematical discourse	IT	2.26 (1.13)	3.17 (0.68)	3.85 (0.42)	p=.009
	DT	N/A	2.84 (0.41)	3.04 (1.19)	n/s
Pose purposeful questions	IT	3.18 (0.79)	3.56 (0.42)	3.88 (0.44)	n/s
	DT	N/A	2.78 (0.51)	3.18 (1.21)	p=.039
Build procedural fluency from conceptual understanding	IT	2.50 (0.78)	3.32 (0.53)	3.77 (0.58)	n/s
	DT	N/A	2.67 (0.47)	3.17 (1.20)	p=.015
Support productive struggle in learning math	IT	2.92 (0.63)	3.54 (0.30)	3.89 (0.28)	p=.024
	DT	N/A	2.77 (0.30)	3.09 (1.10)	n/s
Elicit and use evidence of student thinking	IT	2.23 (0.74)	3.05 (0.45)	3.58 (0.49)	p=.011
	DT	N/A	2.52 (0.43)	2.93 (1.14)	n/s
All domains combined	IT	2.66 (0.48)	3.40 (0.28)	3.82 (0.31)	p=.004
	DT	N/A	2.72 (0.29)	3.04 (1.08)	n/s

Notes. IT = initial treatment group (started MLC in 2013-14 academic year), survey valid n = 13, observation valid n = 14. DT = delayed treatment group (started MLC in 2014-15 academic year), survey valid n = 8, observation valid n = 22. N/A = delayed treatment group was not observed when they were not in treatment.

[a] Paired t-test was performed to assess changes from baseline to post-test using non-missing data.

[b] Wilcoxon signed ranks test was performed due to non-normal distribution of the data. Since delayed treatment group does not have baseline observation ratings, analysis focused on mid-test to post-test.

Table 4. Multilevel mixed-effects linear regression of teacher leadership and data-driven instructional practices on MLC participation over time

	Teacher Leadership		**Instructional Practice**	
Parameters	Estimate	SE	Estimate	SE
Fixed part				
Constant	3.699***	.255	2.722***	.122
MLC participation				
Initial Treatment (IT)	-.887**	.336	.674**	.207
Delayed Treatment (DT)	Reference group		Reference group	
Time				
Baseline	Reference time		N/A	
Mid-test	-.081	.263	Reference time	
Post-test	-.446	.274	.321*	.151
MLC*Time				
IT, Mid-test	.795*	.365		
IT, Post-test	1.303***	.373	.099	.248
Random part				
Between-time variance	.567	.107	.345	.093
Within-time variance	.669	.063	.521	.059
Log likelihood	-129.978		-71.269	

Notes: SE = Standard error. N/A = Analysis omitted baseline observations because delayed treatment group does not have baseline observation ratings.
* p<.05. **p<.01. ***p<.001.

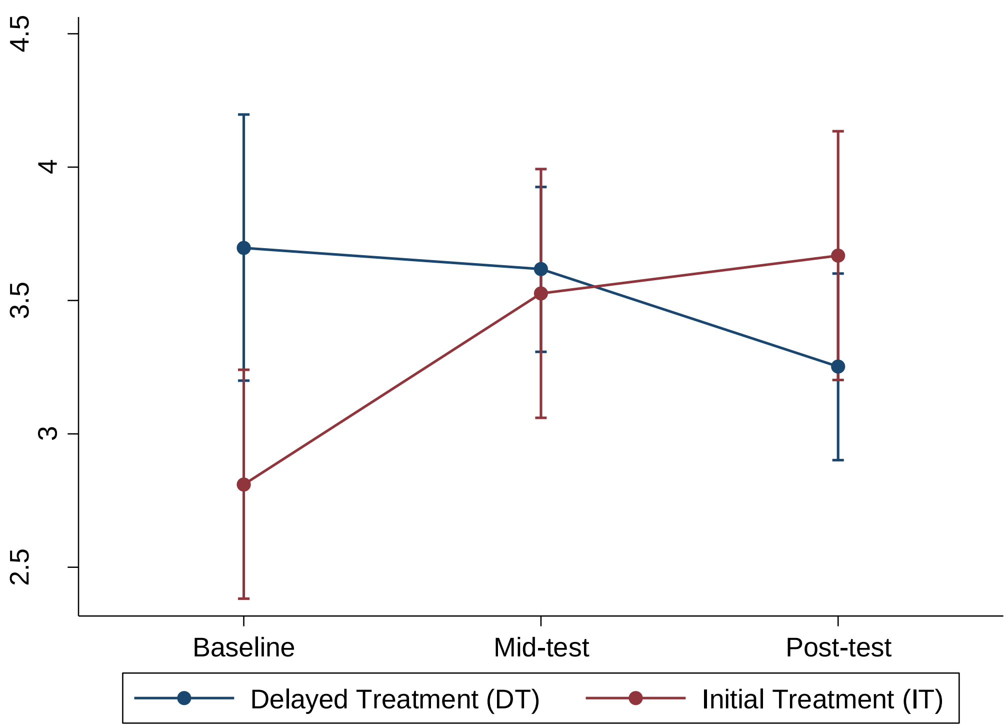


Figure 2. Adjusted prediction of perception of teacher leadership over time by MLC status

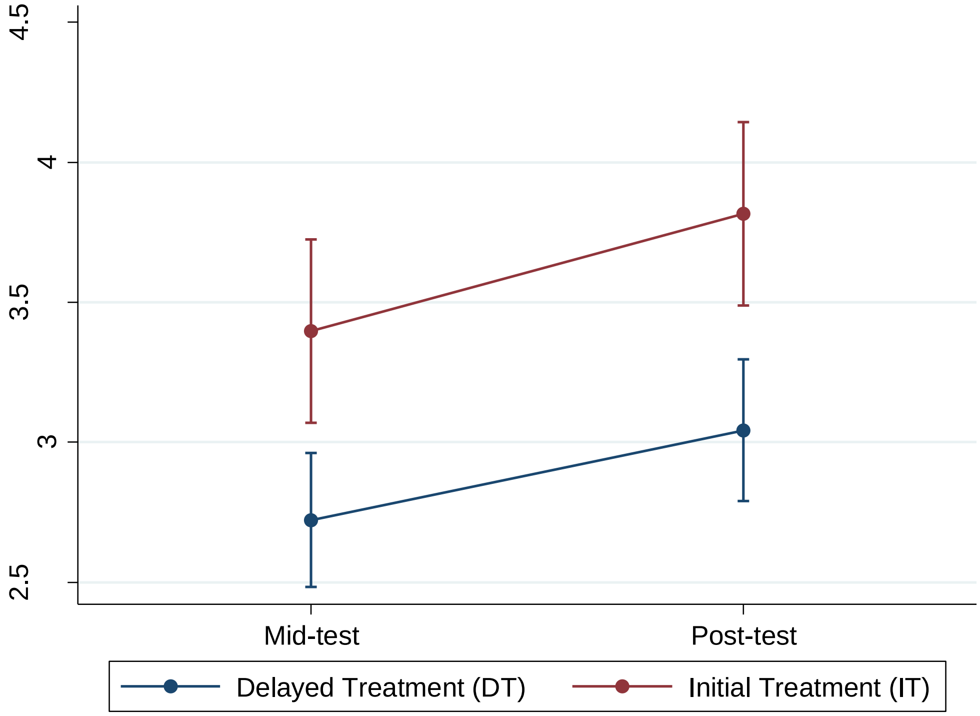


Figure 3. Adjusted prediction of use of data-driven instructional practices over time by MLC status