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SUPPORTING K-10 TEACHERS' INSTRUCTIONAL CHANGES TO PROMOTE THE STANDARDS FOR MATHEMATICAL PRACTICE

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This manuscript describes two cohorts of teachers' instructional changes through the lens of the Standards for Mathematical Practices (SMPs). These teachers participated in a yearlong professional development program targeting the SMPs. Videos of their pre- and post-professional development programs were examined using a SMPs-focused protocol. They offered more opportunities for students to engage in the SMPs after the professional development experience than before the professional development. We connect this impression with ways to effectively foster elementary, middle, and secondary teachers' SMP-focused instructional practices through professional development.

Related Literature

Standards for Mathematical Practice

Many teachers are reevaluating their instruction because of the Common Core State Standards for mathematics (CCSSM; Council of Chief State School Officers [CCSSO], 2010). The CCSSM are composed of content standards, Standards for Mathematics Content (SMCs) and practice standards, Standards for Mathematical Practice (SMPs). The SMPs offer characterizations of behaviors and habits that students should demonstrate while learning mathematics. The *Principles and Standards for School Mathematics* (NCTM, 2000) and *Adding it Up* (Kilpatrick, Swafford, & Findell, 2001) guided the descriptions of the SMPs.

It is clear from literature that teachers' instructional emphasis of the process standards is not occurring often (Hiebert et al., 2005). Such emphasis is connected to promoting students' mathematical proficiency, as described in the CCSSM. Initial research reports about CCSSM implementation suggests that K-12 teachers are struggling to make sense of the SMPs (Bostic & Matney, 2014b; Olson, Olson, & Capen, 2014) much less weave the SMPs into their everyday instruction on the SMCs (Bostic & Matney, 2014a). These findings call for professional development to enhance teachers' understanding of the SMPs and support them to design and actualize instruction that makes the SMPs a part of their mathematics teaching. The purpose of this paper is to build upon the current literature base as a means to discuss K-10 mathematics teachers' instruction, specifically focusing on the ways they provide students' opportunities to engage in the SMPs and its influence on instructional mathematical discourse.

Professional development

A metaanalyis of professional development (PD) suggests that there are some key features to designing effective inservice teacher education (Guskey & Yoon, 2009). Two of those five features include (a) PD activities that encourage teachers to adapt a variety of practices to a content area rather than encouraging a set of best practices and (b) PD activities that encourage teachers to try ideas in their classroom. Boston (2012) details how focusing on implementing worthwhile tasks during a yearlong PD enhanced secondary teachers' knowledge, which in turn influenced their instructional practices. For example, after the yearlong PD they were able to identify elements of tasks with high cognitive demand and concurrently selected more tasks with high cognitive demand for their own instruction. Improving teachers' ability to select worthwhile tasks is not the only way to impact their instructional outcomes (Boston & Smith, 2009); supporting them to establish an effective learning environment and sustain mathematical discourse between students are also necessary to maximize students' opportunities to learn (NCTM, 2007).

In this study, two yearlong projects were conducted in a Midwestern state to prepare teachers to implement the CCSSM. We aim to explore how teachers' instruction changed to support students' engagement in the SMP and attempt to connect their growth to the PD project. Our research question was: How does teachers' instructional encouragement of the SMPs change during the PD? Further, we wondered how teachers' changes might be related to three central areas of this PD: learning environment, worthwhile task, and discourse. We examined K-10 teachers pre- and post-PD mathematics teaching specifically looking for specific instructional actions that are connected to the SMPs.

Method

Context of the Professional Development

We focus on K-10 teachers' experiences as influenced by two yearlong grant-funded professional development programs. Cohorts of K-5 and grades 6-10 (i.e., Algebra 2) mathematics teachers volunteered to be a part of a one-year program during 2013. Teachers met four times for four-and-a-half hour spring sessions between March – April. They met during the summer (June - July) for eight 8-hour days and then again in the fall (August – November) for two face-to-face meetings lasting for four-and-a-half hours each. Teachers were provided with numerous online assignments that were intended to facilitate further online interactions between

March – October that might support teachers' understanding of the SMPs. Generally speaking, the aim of the PD projects included (1) making sense of the SMPs, (2) exploring inquiry through three broad areas consisting of worthwhile tasks, mathematical discourse, and appropriate learning environments, (3) implementing classroom-based tasks that aligned with the CCSSM, and (4) increasing mathematical knowledge and understanding. Teachers read and reflected on their own mathematics instruction, as well as the instruction of others who were implementing the standards. Teachers read and discussed chapters from NCTM books (e.g., Mathematics Teaching Today [NCTM, 2007]) and completed various assignments including reflective journaling, writing, enacting, and reflecting on CCSSM-aligned mathematics lessons, and solving rich mathematics problems.

Participants

This project served 36 K-10 teachers across one Midwest state. Twenty elementary and 16 secondary mathematics teachers participated. Teachers came from urban, suburban, and rural school districts in a Midwest state.

Data Collection and Analysis

Teachers were asked to design, enact, and videotape one lesson during the spring when the PD began and again in the fall, after the PD concluded. Depending on the grade level and the local school context of the teacher, the videos were as short as 25 minutes and as long as 65 minutes. Since our study focused on ways that teachers supported students' engagement in the SMPs during instruction, we investigated the videotapes as a means to best report any instructional changes made during the PD program. Such analysis approaches have been used in similar studies such as Boston (2012) and Boston and Smith (2009).

Data analysis required two parts. The first part involved watching the videotapes and reflecting on instruction using a protocol focused on the ways that teachers' instruction supported engagement in the SMPs. Two mathematics education faculty as well as five mathematics education graduate students watched the videotapes and conducted the analysis using a protocol developed by Fennell, Kobett, and Wray (2013). It provides look-fors that link mathematics instruction with behaviors and actions that are associated with the SMPs. For example, three aspects were used for the first SMP: Make sense of problems and persevere in solving them. They included (a) Involve students in rich problem-based tasks that encourage them to persevere in order to reach a solution, (b) Provide opportunities for students to solve

problems that must have multiple solutions, and (c) Encourage students to represent their thinking while problem solving (Fennell et al., 2013). While there may be other aspects indicative of SMPs, the protocol provides an evidence-based framework for examining mathematics instruction using the SMP lens. Next, we compared our coding observations with one another. When there was a difference in codes, a third coder watched the video and discussed his/her findings with the initial coders. Discussions ended when coders agreed that there was sufficient evidence related to a look-for.

The second part of data analysis focused on making sense of the data to answer our research question. We intended to quantify changes in the number and type of instructional opportunities related to the SMPs. This was accomplished by examining our evidence in two ways. The type and frequency of instructional opportunities related to each SMP were categorized. We summed the total number of indicators for each SMP during pre-PD instruction and compared that grand total to the grand total of indicators for all SMPs seen in post-PD instruction. Summing across all indicators transformed the ordinal data into continuous data thus the sums were examined using a paired-samples t-test. Our continuous data set met the expectations for conducting a t-test (Agresti & Finlay, 2009). Then, we compared the number of indicators observed during pre-PD and post-PD instruction for each SMP using a chi-square test. Finally, we explored the changes in instructional opportunities related to the SMPs across teachers with the goal of generating general impressions. After considering the data, we drew out general impressions that are shared in this manuscript.

Results

Overall, teachers provided more instructional opportunities intended to engage students in the SMPs. Figure 1 shows the frequency of instructional opportunities for each SMP during the pre- and post-PD instructional lesson. A paired samples t-test demonstrated that the overall growth from pre- to post-PD was statistically significant, $t(35) = 12.058$, $p <. 001$, [2.50, 3.51]. The instructional average was 0.94 SMPs indicators in total during pre-PD instruction (SD = .71). Put another way, we found approximately one out of a possible 23 indicators for the SMPs during pre-PD instruction. The post-PD instructional average was nearly three times greater, 3.94 (SD = 1.45). This suggests that we found roughly four unique indicators of teachers' promotion of the SMPs during their post-PD instruction. A closer look into these data indicates that teachers seemed to focus their instruction on promoting some SMPs more than others.

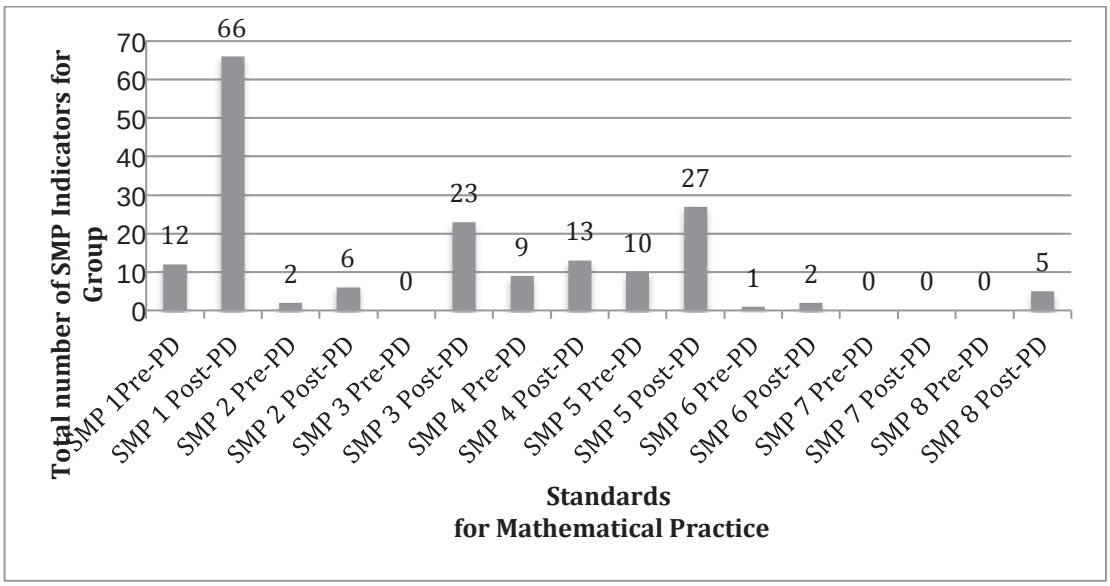

Figure 1. Frequency totals of observed SMPs indicators in pre- and post-PD instruction

We conducted chi-squared tests for group results related to each SMP, correcting for inflated error rates. The goal was to examine whether there were statistically significant differences between number of indicators within a SMP during pre-PD and post-PD instruction. Results are shown in table 2. Our results indicated that teachers' growth was statistically significant in four SMPs: SMP 1, SMP 3, SMP 4, and SMP 5.

Table 1. *Descriptive statistics and chi square results for SMP indicators of Pre-PD and post-PD*

	Pre-PD		Post-PD			
SMP	M	SD	M	SD	X^2	p*
1	0.33	0.48	1.83	0.84	60.92	<.001
2	0.56	0.23	0.17	0.56	4.24	0.06
3	0	0	0.64	0.59	29.65	<.001
4	0.25	0.44	0.36	0.49	15.86	<,001
5	0.28	0.45	0.75	0.6	36	<.001
6	0.03	0.17	0.06	0.23	2.06	0.08
7	0	0	0	0	-	-
8	0	0	0.14	0.42	4.24	0.06

* one-tailed interpretations

Taken collectively, these quantitative findings suggest that on average, teachers provided more opportunities for students to engage in the SMPs after the PD. Looking specifically at each teacher revealed that every teacher provided more opportunities to engage in the SMPs. We

sought to qualitatively understand these changes with respect to the SMPs and three PD factors: learning environment, mathematical task, and discourse. Due to the brevity of this proceedings manuscript, we are only able to provide qualitative description of one teacher's instructional changes.

We noticed that instructional opportunities were clearly influenced by the implementation of their choice of task, changes in learning environment, and ways discourse was promoted. For example, a second-grade teacher's pre-PD instruction focused on guiding students through the definitions of a fraction in the context of exercise-laden teaching. Students were seated in rows and asked to follow her model of using pattern blocks to represent benchmark fractions. Then, students watched a video stemming from her textbook showing exactly the same activity as her students completed just minutes ago. Finally, students worked on a series of exercises without using pattern blocks. Students spoke only when the teacher asked a question. This directed instruction approach stands in stark contrast to her post-PD instruction.

The post-PD warm-up task was to determine how many letters there were in sum of the first names of the class. Students were seated in small groups and had access to a variety of manipulatives on their desks. The teacher encouraged several students to share how they counted the letters. After the warm-up task, she asked them to determine the number of legs in the classroom. The teacher utilized a think-pair-share approach with this task. Students used an initial representation (e.g., symbolic, graphical, verbal, and/or concrete) to solve this task and the teacher monitored students' work. She reminded students to explain what they were doing on their papers and to be prepared to justify why their approach is effective and efficient. As students finished working with an initial representation, she asked them to employ another viable representation to solve the problem. Finally, students shared how they solved the problem using multiple representations and then justified their strategy to a partner and then the class. Students also responded to questions from the teacher but the flow of discourse included multiple student-to-student interactions as well. It was apparent how the teacher provided an opportunity for her students to decontextualize the mathematical elements from the task and later contextualize the mathematical symbols with the referents in the problem. Through these instructional changes and ones like it, our sample of teachers provided greater instructional opportunities for students to engage in the mathematical practices.

Implications

From this study, we learned that teachers overwhelmingly engaged in greater opportunities related to the SMPs after the PD than before it. These changes are associated with modifications to the learning environment, mathematical task, and/or ways that the teacher initiated and sustained mathematical discourse. For example, the second-grade teacher's post-PD changes are tied to all three instructional aspects. These changes led to greater opportunities to foster students' engagement in the SMPs. While it is beyond the scope of the research to link one aspect of the PD with these changes, the results more broadly suggest that yearlong PD focusing on the CCSSM and our three central instructional aspects led to changes in the way these K-10 teachers designed and implemented mathematics instruction. The SMPs do not dictate curriculum or teaching but they do provide ideas for mathematically engaging students in classroom instruction. Sustained PD of a year or longer may help mathematics teachers at all grade levels make sense of mathematics instruction that supports students' appropriate mathematical behaviors. Results from this study support the prior literature suggesting that yearlong PD, which adheres to what works for designing and implementing effective PD (NCTM, 2007), tends to lead to instructional changes that promote improved opportunities to learn.

Limitations

Qualitative approaches allow researchers to draw on their lenses and frames of reference to make sense of experiences in the world. The results offered here are not generalizable to all teachers and are particular to this set of teachers. Our sample also limits some of the findings. That is, teachers volunteered to participate in the PD and those who are less motivated to complete yearlong PD may have different outcomes making instructional changes. Furthermore, teachers differing in some way from our sample in terms of years of experience, school district location, or other aspects might lead to other findings. A third limitation was that the pre-PD video was done after nine hours of Common Core PD. Thus, any growth in teachers' promotion of the SMPs is limited because they experienced some PD prior to their pre-PD instructional video.

Conclusion

The third limitation provides an important finding about the importance of our yearlong Common Core PD program. Teachers had another 78 hours of PD following their pre-PD videos,

which is a strong indication of the impact that sustained PD has on teachers' instructional outcomes. That is, teachers provided limited opportunities for students to engage in the SMPs after nine hours of PD, yet improved greatly after more time to consider their PD experiences and translate them into pedagogical instantiations to promote the SMPs. The evidence found in this study suggests that K-10 teachers benefitted from reflecting and working to implement the CCSSM through three instructional areas: learning environment, mathematical task, and mathematical discourse.

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