NOVICE ELEMENTARY TEACHERS' INSTRUCTIONAL PRACTICES: OPPORTUNITIES FOR PROBLEM-SOLVING AND DISCOURSE

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The purpose of this study was to examine the mathematics instructional practices of 75 second-year elementary teachers (K-5) in terms of the learning opportunities provided to their students. On average, each teacher completed instructional logs for 43 days across the school year. Select items were analyzed in order to better understand the elementary students' opportunities to engage in problem solving and discourse. Results indicated frequent opportunities for discussion but limited opportunities for engagement with more open-ended tasks and explanation. Implications for future research and mathematics teacher education are discussed.

Keywords: Classroom Discourse; Problem Solving; Instructional Activities and Practices; Elementary School Education

Purpose

Elementary teacher preparation programs strive to prepare high-quality teachers in the field of mathematics by increasing content and pedagogical knowledge through methods courses (Burton, Daane, & Giesen, 2008) and providing beneficial field experiences (Darling-Hammond, Chung & Frelow, 2002; O'Brian, 2007). However, all elementary teachers, including early-career teachers, continue to struggle to enact standards-based mathematics instruction due to variety of reasons including knowledge deficits (Mewborn, 2001), anxiety with mathematics (Bekdemir, 2010; Bush, 1989), and deep-rooted beliefs about the nature of the discipline (Raymond, 1997; Wilson & Cooney, 2002). Early-career teachers, whom we will call "novices" in this paper, also face challenges associated with induction into the profession such as learning to manage a classroom of students with varying needs and developing lessons on new topics (Feiman-Nemser, 2003).

All of these aforementioned factors affect instructional choices of novice elementary teachers; therefore, it is important to understand their enacted mathematics instructional practices in order to inform the work of elementary teacher preparation in mathematics. Little is known about the mathematics instructional practices of novices; existing research has looked at instruction generally rather than focusing on mathematics (e.g., Ingersoll & Strong, 2011). The current study aims to begin to fill this void in the literature by examining the mathematics instructional practices of elementary teachers during their second year of teaching. Specifically, the research questions guiding this study were:

1. What instructional practices, relative to problem solving and discourse, do novice elementary teachers utilize during mathematics lessons?
    a) What instructional practices are utilized in the primary grades (K-2)?
    b) What instructional practices are utilized in the upper elementary grades (3-5)?
2. How do instructional practices of novice teachers, specifically in problem solving and discourse, vary across their own mathematics lessons and in comparison to other novice teachers?

Theoretical Framework and Related Research

This study examines mathematical instructional practices using the *Opportunity to Learn* framework (OTL). That is, we are interested in the learning opportunities of elementary students during mathematics lessons. Initial research utilizing OTL emerged from evaluation work analyzing

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curriculum coverage as a measure of the opportunities students have to engage with certain topics (McDonnell, 1995; Wang, 1998). In more recent work, OTL has been applied to international comparison research (Floden, 2002), analysis of instructional strategies (Bell & Pape, 2012), and influences of diversity on opportunities for students (Tate, 2005). This study explores the opportunities given to students in novice teachers' classrooms to engage in particular mathematical practices or processes.

These mathematical processes were outlined in standards released by the National Council of Teachers of Mathematics (NCTM) in 2000. Then, the 2010 release of the Common Core State Standards for Mathematics (CCSSM) included a continued emphasis on students' mathematical practices as a critical component of K-12 mathematics instruction (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Two processes that are evident in these standards documents include students' opportunities to engage in *problem solving* and *discourse*, the foci of this study.

Problem solving refers to students' opportunities to grapple with mathematical problems to which they do not already have a solution method to use (NCTM, 2000). Furthermore, when students are given opportunities to demonstrate more than one method for solving a problem, they have the chance to demonstrate their ability to think flexibly. The nature of the tasks given to students translates to their opportunities to engage (or not engage) in problem solving (Stein, Smith, Henningsen, & Silver, 2009).

Past research in student discourse has shown that student interactions are a means of engaging as mathematicians (Nystrand, 2003; Herbel-Esienmann, 2009). Subsequent work by Bell & Pape (2012) analyzed the opportunities to learn that were created through social interactions, and this current study extends that line of research by exploring the opportunities students have to engage in discourse about their mathematical work.

Giving students opportunities for problem solving and discourse during mathematics has been proven to be challenging for elementary teachers (Walkowiak, 2010), but it can be particularly difficult for novice teachers. Research has shown that novice teachers are more likely to be concerned with management (Melnick & Meister, 2008), creating a different context for instructional decision making. However, research concerning enacted practice is limited when considering the novice teacher population. Much of the literature documenting novice teachers' practices are couched in induction and mentoring research and only looks at small samples of teachers. Also, this literature base examines teaching practices with broad strokes and not with a specific lens on mathematics education (Ingersoll & Strong, 2011).

Methods

Participants

The participants were 75 second-year elementary teachers, from a southeastern state in the United States. All teachers graduated from a public teacher preparation program within the state and were employed by a public elementary school. Propensity score matching was used to match teachers on aptitude scores (SAT, ACT) and other college-entry characteristics. Of the 75 participating teachers, 47 taught primary grades (K-2), and 28 taught upper elementary grades (3-5).

Measure

As part of a larger grant-funded project (Project ATOMS), the Instructional Practices Log in Mathematics (IPL-M) was created to measure the extent (as a proportion of time) to which certain instructional practices were present in a mathematics lesson. Within the log, teachers used a 4-point Likert scale (not today, little, moderate, and considerable) to respond to items beginning with the question stem, "During today's instruction, how much time did the students in the target class…"

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Teachers used the scale response of "not today" to indicate when students did not engage in an instructional practice, and they used "little" to indicate when the practice was used for a brief amount of time. On the other hand, teachers chose "moderate" when the practice was used for a substantial amount of time but not the majority of the lesson, and teachers used the response "considerable"

Table 1: Percentage of Elementary Lessons Utilizing Instructional Practices

	Not Today	Little	Moderate	Considerable
Nature of the Task				
Work on exercises specifically for practice or review K-5	22.9	27.8	25.6	23.6
K-2	27.1	26.7	22.8	23.5
3-5	14.6	30.1	31.3	24.0
Listen to me explain the steps to a procedure K-5	42.1	42.0	14.0	1.9
K-2	44.4	40.8	13.2	1.6
3-5	37.6	44.4	15.5	2.5
Perform tasks requiring ideas or methods already introduced to the students K-5	11.0	23.7	28.4	36.9
K-2	10.1	24.0	29.6	36.4
3-5	13.1	23.1	25.9	37.9
Perform tasks focused on math procedures K-5	51.9	20.8	16.3	11.0
K-2	59.2	20.0	13.8	7.0
3-5	37.1	22.6	21.1	19.0
Perform tasks requiring ideas or methods NOT already introduced to the students K-5	55.1	23.2	14.3	7.4
K-2	57.4	23.2	13.3	6.0
3-5	50.4	23.2	16.4	10.2
Work on problem(s) that have multiple answers or multiple solution methods K-5	58.3	17.7	15.3	8.7
K-2	59.9	17.1	14.8	8.2
3-5	54.9	18.9	16.4	9.8
Demonstrate different ways to solve a problem K-5	53.9	23.8	15.2	7.1
K-2	56.3	23.8	13.3	6.5
3-5	49.1	23.6	19.0	8.3
Discourse				
Discuss ideas, problems, solutions, or methods with other students in small groups or pairs K-5	26.6	30.9	26.4	16.2
K-2	32.1	30.0	22.9	15.0
3-5	15.3	32.7	33.5	18.5
Discuss ideas, problems, solutions, or methods in large group K-5	20.6	35.3	28.4	15.6
K-2	21.3	34.7	27.9	16.1
3-5	19.2	36.6	29.4	14.7
Explain orally his/her thinking about mathematics problems K-5	31.9	36.7	26.1	5.4
K-2	33.8	37.1	24.8	4.3
3-5	28.1	35.7	28.7	7.5
Talk about similarities and differences among mathematical representations K-5	50.9	28.6	15.8	4.7
K-2	54.2	28.1	14.2	3.6
3-5	44.2	29.4	19.2	7.1
Talk about similarities and differences among various solution methods K-5	66.6	29.9	10.9	2.6
K-2	70.3	18.9	8.8	2.0
3-5	59.2	22.0	15.0	3.8

when a practice was used for more than half of the lesson. In addition to student activities, teachers also responded on items about the time and content focus of the lesson. As part of validation work on the log, a Kappa coefficient of .69 (Z=6.30, p<.001) was calculated between live observer and teachers' log responses to indicate there is evidence that teachers are reliably reporting the practices as stated in the items.

Instructional logs, like any measure of instruction, provide affordances for studying classroom instruction along with limitations (Rowan & Correnti, 2009). When compared to observational measures, which are often seen as the gold standard in the measurement of teaching practices, logs allow for sizable increases in number of lessons that can be examined. Additionally, in light of educational surveys that require teachers to reflect on instruction from previous weeks or months, daily logs reduce the error that comes with retrospection. Lastly, while logs are criticized due to self-report, past work has shown that with training and proximity of logging to time of instruction, teachers can reliably report on their instruction (Rowan, Jacob, & Correnti, 2009).

To support the reliability of log responses, each teacher attended a regional, two-hour training on the IPL-M. During this training teachers were provided with detailed explanations of items that were vulnerable to misinterpretation. In addition to item explanations, teachers practiced with scales and the online interface. Also, teachers were required to log as soon after instruction as possible and utilized a user's manual to support their understanding of the items.

Data Collection and Analysis

The teachers logged at three different time points throughout the 2013-2014 school year, with approximately 15 days per time point. Teachers logged for a range of 11 to 58 total days (M=42.83, SD=8.99) with each day corresponding to one mathematics lesson. A total of 2,741 mathematics lessons were logged with 1,837 being K-2 lessons and 904 being 3-5 lessons.

Descriptive statistics were analyzed using SPSS for items on the log. Lessons were analyzed to determine what percentage of lessons included opportunities for problem solving and discourse as demonstrated by the extent to which certain practices were or were not utilized in the lessons. Next, lessons were aggregated and analyzed based on primary (K-2) and upper elementary (3-5) grade bands.

Lastly, Intraclass correlations (ICCs) were calculated using a multi-level model approach within SAS to determine the amount of within- and between-teacher (Raudenbush & Bryk, 2002). That is, due to the nested nature of the data, a multi-level approach is necessary to account for how an individual teacher's instructional practices vary from lesson to lesson and how his/her practices vary from other teachers.

Results

Description of Instructional Practices for Full Sample of K-5 Teachers: RQ #1. Table 1 presents the percentage of all lessons in which students engaged in the instructional activity detailed in the item. The items are organized based on the *nature of task* and *discourse.* The items within these two constructs provide insight about students' opportunities (or the lack thereof) to engage in problem solving and talk about the mathematics. As we present the results, we focus on students' opportunities to engage in the instructional practices for a substantial amount of time by reporting the percentage of lessons in which the practice occurred for a moderate or considerable amount of time

Some of the log items within *the nature of the task* category describe instructional activities that more prescribed in nature such as "perform tasks focused on math procedures" and "work on exercises specifically for practice or review," while other items such as "Work on problem(s) that have multiple answers or multiple solution methods" are more indicative of tasks of higher cognitive demand with opportunities for problem solving. Two of the log items within the *discourse* category describe general opportunities for students to talk about the mathematics such as "discuss ideas,

problems, solutions, or methods with other students in small groups or pairs." Other log items in this category such as "talk about similarities and differences among representations," provide more detail about the aspect of the mathematics in which the discussion is focused.

In 65.3% of K-5 lessons, students were engaging with tasks that they had already learned an idea or method to use to solve for a substantial amount of the lesson (moderate or considerable amount of time). In contrast, only 21.7% of lessons involved a longer span of time allocated for students to perform tasks without having a predetermined way to solve it (perform tasks requiring ideas or methods NOT already introduced to the students). Furthermore, 24% of lessons involved students working on problems with more than one answer or way to solve, and 23.2% of lessons included students demonstrating these different ways. These two items describe problems that were more open-ended in their solutions or solution methods. These types of problems are more amenable to elevating the cognitive demand based on the different ways students can approach the problem and possible comparison of solution methods (Stein, Lane & Silver, 1996); therefore, when utilized, the opportunity is present for higher levels of cognitive demand.

As shown under the discourse section of the Table 1, teachers reported 42.6% of lessons involved a substantial amount (moderate or considerable) of small group or pair discussion, and 44.0% of the lessons involved a moderate or considerable amount of whole group discussion. However, lower percentages of lessons are reported that utilized moderate to considerable amounts of time for student explanations (31.5%), talk about similarities and differences among representations (20.5%), and talk about similarities and differences in solution methods (13.5%).

Description of Instructional Practices of K-2 versus 3-5 Teachers: RQ #1a&b. Table 1 also presents the percentage of lessons by grade bands in regard to the use of instructional practices. For several of the practices, such as "perform tasks requiring ideas or methods already introduced to the students," primary and upper elementary lessons look similar in terms of the extent of the lesson utilizing this instructional practice. Other items show differences in the grade bands, such as "perform tasks focused on math procedures" and "discuss ideas, problems, solutions, or methods with other students in small groups or pairs." Upper elementary lessons have a higher percentage of lessons involving these practices, which can be expected due to content goals focused on mastery of algorithmic processes for addition, subtraction, and multiplication, and the increase in maturity and attention span to engage in small-group conversations with peers.

Also, as aforementioned, few lessons included the opportunity for students to discuss similarities and differences in representations and solution methods. When further aggregating the lesson percentages, K-2 lessons are limited (17.8% and 10.8% respectively) in the opportunities for these types of discussions.

Examining variance within and between teachers: RQ #2. Table 2 presents the Intraclass correlations (ICC) for the instructional practice items on the mathematics log. The ICCs represent the proportion of variability in how that item was reported between teachers. The higher the ICC, the more variability can be attributed to differences in teachers. The lower ICC indicates that more of the variability can be attributed to the differences an individual teacher's lessons across time. For example, the item, "Perform tasks requiring ideas or methods already introduced to the students," has an ICC of 0.12, which represents that 12% of the variance in that items response rate is attributed to differences between teachers (i.e., between-teacher variance) while 88% of the variance is attributed to the variation across lessons for individual teachers (i.e., within-teacher variance).

The items related to the opportunity for problem solving have a wider range of ICC values, .12-.48. Items "Perform tasks requiring ideas or methods already introduced to the students" and "Perform tasks requiring ideas or methods NOT already introduced to the students" have lower ICCs (.12 and .17 respectively), and therefore seem to vary between lessons rather than between teachers. The discourse items presented in Table 2 range in ICC values from .23-.33, with 33% of the variance

Table 2: Intraclass Correlations for Log Items

Log Item	Intraclass Correlation
Perform tasks requiring ideas or methods already introduced to the students	0.12
Perform tasks requiring ideas or methods NOT already introduced to the students	0.17
Work on exercises specifically for practice or review	0.20
Discuss ideas, problems, solutions, or methods in large groups	0.23
Work on problem(s) that have multiple answers or multiple solution methods	0.23
Discuss ideas, problems, solutions, or methods with other students in small groups or pairs	0.24
Demonstrate different ways to solve a problem	0.25
Listen to me explain the steps to a procedure	0.26
Talk about similarities and differences among mathematical representations	0.30
Talk about similarities and differences among various solution methods	0.31
Explain orally his/her thinking about mathematics problems	0.33
Perform tasks focused on math procedures	0.48

in the responses to the item "explain orally his/her thinking about mathematics problems" being between teachers.

Discussion

These analyses provide a glimpse into novice teachers' mathematics classrooms and the opportunities students have to engage in various practices. The instructional log used in the study shows promise in its ability to document the practices teachers are using, as seen by the distribution of responses and evidence of variability even with a relatively homogenous sample of teachers (novice, formally prepared teachers). Logs have been used in past research (Rowan, Harrison & Hayes, 2004; Stecher, 2006), but the IPL-M was carefully designed to align with mathematical practices and processes (CCSSM, 2010; NCTM, 2000). The ability to collect data on a large amount of lessons in a relatively efficient manner makes the log an advantageous tool for teacher educators and researchers to understand teachers' instructional practices during mathematics.

In looking at the descriptive log data, three themes emerged. First, it seems that majority of lessons are focused on tasks that more prescribed in nature. These lessons utilized methods that have already been taught or focused on review and practice. This aligns with findings from Rowan, Harrison, & Hayes (2004) that approximately 70% of elementary lessons from a more experienced teacher sample involved direct teaching with known ideas. Although international comparisons imply that U.S. teachers need to engage students in more opportunities to grapple with mathematics, it seems there is still a tendency to over structure our students' learning opportunities by presenting the mathematical procedures that they then need to practice. While it is important not to detract from the value of practice and the need to review, we need to be simultaneously critical of the proportion of lessons devoted to these goals. For a novice teacher, this might be especially difficult due to the newness of navigating pressures of curriculum pacing and student assessment.

The second theme that emerged from analysis of descriptive information is the presence of student talk in novice teachers' lessons. Teachers reported that majority of lessons included small group or whole group discussion for a substantial amount time in the lesson. This paints the picture of interactive classrooms, in contrast to the lecture-style environment with which traditional mathematics is often associated. Also, ICCs of the items indicating whole group and small group discussion were .23 and .24, respectively, meaning that over 20% of the variance in utilizing these modes of discourse is between teachers. Future steps will be employed to try to account for the contextual factors or teacher characteristics that explain this variance. Understanding why some

novice teachers implement more discussion than others would provide important implications for elementary mathematics teacher educators.

The third theme emerges from a closer look at the opportunities for student discourse. Although a majority of the lessons involved some level of whole or small group discussion, other items provide supplemental information about the nature of the discourse in these discussions. Approximately 30% of lessons involved student explanation for a substantial amount of time, and an even smaller proportion of lessons had students discussing similarities and differences among representations and/or solution methods. It seems that students have the opportunity for classroom discussions, but they may be limited in their opportunities to engage in discourse specific to mathematical representations and ways of solving problems. This seems supported by the lower percentage of lessons involving open-ended tasks or multiple solution methods. Furthermore, the ICCs of items detailing the nature of the discussion (explain, discuss similarities in representations and/or solution methods) were each approximately .30 indicating that about 30% of the variation in these items can be attributed to the teacher. So while lessons vary in the opportunities for students to engage in specific discourse practices, overall some teachers are engaging in these practices more than others.

As preservice and inservice teacher educators strive to equip teachers to implement high-quality mathematic instruction, this work provides valuable insight into the instructional practices that novice teachers are utilizing. While it is encouraging that teachers are engaging students in opportunities for discussion, methods courses might further strengthen teachers' instruction by making more explicit how teachers can specifically prompt students to discuss aspects of mathematical ideas such as explaining or comparing solution strategies. Our next steps with this data and ongoing data collection are to begin to analyze the contextual factors that might account for teacher variance on the use of certain practices. This will provide teacher educators with important information to help support novice teachers and help break the detrimental cycle of reverting back to practices based on past experiences and anxiety.

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