SIMULATING A PEDAGOGY OF ENACTMENT MAY WORK FOR SOME EARLY NUMERACY TEACHERS BUT NOT OTHERS

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The Numeracy Kit for Kindergarten 5-Year-Olds (NyKK-5) is a tool to support kindergarten teachers' numeracy practices. Based on a pedagogy of enactment, the NyKK-5 was designed to simulate the types of in-class supports that have been identified as critical elements of effective mathematics professional development (PD). Two groups of teachers received PD on children's early numeracy: The NyKK-5 condition was provided the NyKK-5 and the theory condition was not provided any pedagogical tools. Students in the NyKK-5 and theory classrooms demonstrated greater numeracy growth relative to students in a comparison condition. Teacher logs and classroom observations suggested that the amount of time spent engaging students in mathematics was more predictive of student learning than the NyKK-5 by itself, but the amount of teaching experience may define one condition under which use of the tool is optimized.

Keywords: Professional Development; Early Childhood Education; Number Concepts and Operations

Young children's number sense is predictive of their future mathematical development, and kindergarteners who fail to acquire early numeracy skills tend to fall behind their peers as they advance through school (Aunola et al., 2004; Jordan et al., 2010). As such, teachers who provide a strong numeracy foundation in the early years play an important role in their students' future academic success (Presser et al., 2015; Starkey et al., 2004). Early childhood educators, however, need support to establish these numeracy foundations in their classrooms (Ginsburg et al., 2008). In the present study, we investigated the impact of a professional development (PD) initiative for kindergarten teachers centered on a "pedagogy of enactment" (Grossman & McDonald, 2008, p. 189). Our goal was to examine the effect of the professional development on children's numeracy over the course of the kindergarten year and to use descriptions of the teachers' classroom practice to explain the findings.

Situating Early Numeracy Professional Development in Practice

Early numeracy education centers on rich teacher-student conversations around numeracy concepts, where teachers capitalize on teachable moments during play and continually adjust instruction to respond to students' in-the-moment, educational needs (Ginsburg & Ertle, 2008; Jacobs & Empson, 2016). Creating this kind of learning environment requires a profound knowledge of students' numeracy development (Ball et al., 2008; Even & Tirosh, 1995), which enables teachers to notice and interpret students' understanding, appropriately respond in the moment, and make informed instructional decisions to advance their learning (Ghousseini & Sleep, 2011; Ginsburg & Ertle, 2008; Jacobs & Empson, 2016; Stahnke et al., 2016).

Lamberg, T., & Moss, D. (2023). *Proceedings of the forty-fifth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (Vol. 1). University of Nevada, Reno.

Although attending to children's mathematics thinking is a key characteristic of effective PD (Carpenter et al., 1989; Hawes et al., 2021), it is not sufficient: PD must be sustained and situated in the practice of teaching (Ball & Cohen, 1999; Borko et al., 2010). Such a pedagogy of enactment approach to PD entails *in situ* supports during the act of teaching, which are effective because they enhance teachers' ability to incorporate newly-acquired PD content into their daily instructional routines (Ball & Forzani, 2009; Hiebert & Morris, 2012; McDonald et al., 2013). Regrettably, such PD is often resource intensive and rarely sustainable in the long run. In the absence of prolonged in-class support from school leaders and mathematics coaches (see Gibbons et al., 2017, for an example), teachers need alternative resources to help them make instructional decisions in the moment, particularly within messy classroom environments that contain many demands on their attention. We posit that usable devices, such as a toolkit, may act as a suitable proxy for these in-class supports.

We developed the Numeracy Kit for Kindergarten 5-year-olds (NyKK-5) to act as a surrogate for the in-context supports that have been identified in previous research as an essential component of effective professional development (e.g., Ghousseini & Sleep, 2011). The NyKK-5 is a collection of activities and corresponding materials based on a set of core early numeracy skills that have been found to be predictive of children's achievement in the first grade and beyond (Jordan et al., 2007; Jordan et al., 2009; Navarro et al., 2012). Teachers can use the kit to enact numeracy activities in the classroom and formatively assess their students' mathematical thinking. It is portable and designed for teachers to use on the fly to plan their lessons, interpret their students' thinking, and make decisions about instructional moves that are responsive to their students' learning needs (Jacobs & Empson, 2016).

Present Study

Our primary research objective was to investigate whether the use of the NyKK-5 in kindergarten classrooms adds value to children's numeracy growth beyond PD content on children's numeracy development alone. We assigned teachers to one of three PD conditions: (a) NyKK-5: PD on children's thinking about core numeracy skills and on the contents and use of the NyKK-5; (b) theory: PD on the development of children's thinking about core numeracy skills, but without the NyKK-5; (c) comparison: a non-numeracy PD. We assessed children's numeracy growth over the school year to determine whether differences emerged between conditions. Because the NyKK-5 was designed to support teachers' in-the-moment decisions about their instructional practice, we predicted that the growth in students' learning would be greater in the NyKK-5 condition relative to the other two conditions. We also predicted that the students in the theory classrooms, because of the focus on children's thinking, would experience greater numeracy growth than the students in the comparison condition.

The second objective was to explain any condition effects using data on teachers' classroom practices. Teachers completed daily teacher logs and researchers conducted classroom observations on the teachers' enactment of PD-related material. These data were collected to lend insight into how teachers responded to the NyKK-5 and the conditions under which its effects could be maximized.

Method

Participants

Participating teachers and their students were recruited from six public schools in a large urban school board in Canada. The eight participating kindergarten teachers all identified as

women and had between 2 to 29 years of teaching experience.

The student sample consisted of 104 kindergarteners. Because of absence (1 student), lack of assent (2 students), and missing data on the numeracy assessment (5 students), there were 96 students in the final sample. The participants had a mean age of 66.8 months (SD = 4.00) at pretest and 72.9 months (SD = 3.93) at posttest (41.1% girls; 58.9% boys; 0% other gender). Parents of participating students reported their household income in Canadian dollars on a demographic survey. We used these data as a proxy measure for family socioeconomic status. Almost a quarter (24%) of the participants did not respond or provided unusable responses to the question. Of those who did respond, 2.7% had an income less than $20,000, 9.6% had an income between $20,000 and $40,000, 11.0% had an income between $40,000 and $60,000, 5.5% had an income between $60,000 and $80,000, 6.8% had an income between $80,000 and $100,000, and 64.4% had an income over $100,000.

Design and Procedure

We used a quasi-experimental pretest-intervention-posttest research design where the teachers were assigned to one of three professional development conditions: (a) the NyKK-5 condition (4 teachers; n = 40 students) received professional development on children's numeracy and were given the NyKK-5 to use in their classrooms; (b) the theory condition (2 teachers; n = 27 students) received the same professional development on children's numeracy, but were not given the NyKK-5; and (c) the comparison condition (2 teachers; n = 29 students) received professional development on children's general cognitive development and accompanying activities, but with no focus on numeracy. Because of logistical constraints, we were unable to fully randomize the assignment of teachers to conditions.

We assessed the kindergarteners' numeracy skills at the beginning (October–November 2021) and end (April–May 2022) of the school year. The teachers began applying the resources they received in the PD in January 2022. Teachers completed daily teacher logs on their engagement in PD-related classroom activities for 17 weeks between January and April. Two research assistants also visited each teacher's classroom three times between January and April for classroom observations.

NyKK-5

The NyKK-5 is a collection of activities and manipulatives in a plastic case (dimensions: 15" x 12"x 5") that teachers can easily carry around in the classroom. In the case are colored plastic boxes, each corresponding to one of six specific numeracy skills: subitizing, counting, number knowledge, non-verbal calculation, story problems, and part-whole combinations (Jordan et al., 2007). The boxes in the NyKK-5 contain a variety of activity cards for each target skill, including sample questions to assess it and suggestions for follow-up prompts. Matching boxes contain manipulatives corresponding to several of the activity cards. The activities can be used in a variety of settings, including in one-on-one conversations with children, in the context of small group work (e.g., math centers), or with the whole class. Furthermore, the kit was designed to support responsive teaching (Jacobs & Empson, 2016) – that is, teachers can use it for formative assessment and to select follow-up instructional activities in response to students' mathematical thinking. Sample scenarios were provided during the professional development to illustrate the types of activities that could be selected as a function of student thinking.

Professional Development

The third and fourth authors facilitated all PD sessions in the study.

NyKK-5. Teachers in the NyKK-5 condition participated in three full-day PD sessions for a total of 18 hours. The content focused on the development of children's thinking in the six

numeracy domains reflected in the NyKK-5. The teachers examined the contents of each box in the kit, explored how the contents addressed the six target numeracy skills, and reflected on how to use each component of the kit in their classrooms.

Theory. Teachers in the theory condition participated in two full-day PD sessions for a total of 12 hours. They received identical PD to the NyKK-5 condition but were not provided the NyKK-5 or any materials for classroom use.

Comparison. Comparison teachers participated in one 6 hr session on children's general cognitive development in the domains of creativity, collaboration, communication, and critical thinking. No information on children's numeracy was provided. Teachers were given a box of assorted LEGO® bricks and selected activities from the LEGO® Education program to support the cognitive development of young children in their classrooms (Hugo, 2016).

Measures

Student Numeracy Skills. We assessed children's early numeracy skills using a modified version of the Preschool Early Numeracy Screener-Brief Version (PENS-B; Purpura et al., 2015). The PENS-B is a measure of students' global numeracy that includes items related to the various skills shown in previous research to be critical for students' early mathematical development (e.g., Jordan et al., 2007). The skills assessed verbal counting, one-to-one counting, cardinality, counting a subset, subitizing, numeral comparison, set comparison, number order, numeral identification, set-to-numeral, story problems, number combinations, relative size, and ordinality. The PENS-B comprises 25 items, with a maximum possible score of 29. The verbal counting item is scored from 0 to 5 based on the highest number to which the participant can count, and the remaining items are scored as 0 or 1 (incorrect or correct, respectively).

Teacher Logs. On each day over 17 weeks, teachers reported whether they engaged in PD-related activities and if so, they selected from a list which specific PD skills they targeted. Teachers in the NyKK-5 and theory conditions chose from the following numeracy skills: subitizing, counting, number knowledge, non-verbal calculation, story problems, and part-whole combinations. Teachers in the comparison condition chose all that applied from creativity, communication, critical thinking, and collaboration.

Classroom Observations. Two trained research assistants observed each teacher in the classroom engage in PD-related activities three times between January and April. Each observation lasted 30 min comprising four blocks of 7 min each. Each block began with a 3-min time sampling observation of the teachers' pedagogical moves. The time sampling consisted of 5-s intervals (36 in total over the 3 min) with observations conducted in every odd-numbered interval. Using a prepared checklist, the observers selected from the following mathematics teaching moves: used declarative statements about mathematics, modeled mathematical activity to their students, asked their students questions about the topic, and listened and observed their students engage in a mathematical task. Non-mathematics behaviors were classified as "other."

The observers spent the next 3 minutes taking field notes to describe the activity observed during the preceding 3-min observation period. The observers then took a 1-min break before starting the next observation block. At the end of the four observation blocks, each observer took additional field notes to document any methodological challenges. The data used in the subsequent analyses comprise the observations of the teachers' interactions with their students during 216 coding intervals (3 observation sessions x 4 blocks x 18 time-sampling intervals). The observers had an interrater reliability of 89.5% across all 12 time-sampling blocks.

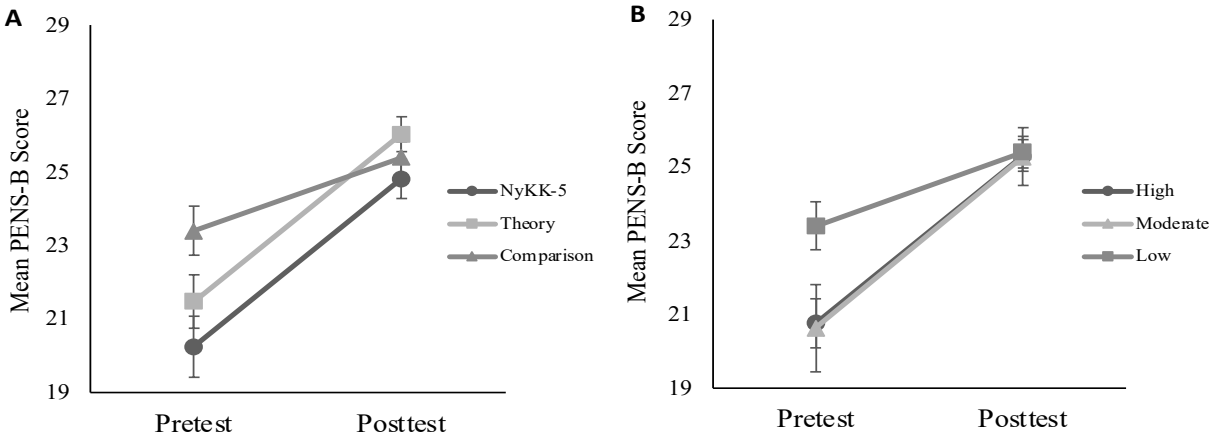
Results

In this section, we report on the effects of PD condition on students' numeracy growth over the course of the kindergarten year. This is followed by an examination of the teachers' classroom practices, as measured by the teacher logs and classroom observations, to augment our account of students' numeracy development in relation to the PD delivered and teacher individual differences.

We first conducted a preliminary analysis to determine whether children's household income should be included in subsequent models testing the factors related to students' numeracy growth. A chi-square test of homogeneity revealed that there were no differences in the proportion of students from higher-income households (> $100,000) and lower-income households (< $100,000) between conditions, $\chi^2(2, N = 73) = 2.13$, $p = 0.34$.

Students' Numeracy Growth

Our first objective was to investigate whether the NyKK-5 added value to children's numeracy gains beyond the theory on children's numeracy development alone. Means and standard deviations on the PENS-B by time and condition are presented in Panel A of Figure 1. A one-way analysis of variance (ANOVA) on the PENS-B gain scores revealed a statistically-significant effect of condition, $F(2,93) = 6.41$, $p = .002$, $\eta^2 = .24$. Follow-up Least Significant Difference (LSD; Levin et al., 1994) pairwise comparisons indicated that both the NyKK-5, $t(93) = 3.27$, $p = .002$, and the theory conditions, $t(93) = 2.96$, $p = .004$, improved more over time than the comparison condition, but no difference was found in students' numeracy gains between the NyKK-5 and theory conditions, $t(93) = 0.02$, $p = .98$. These results suggest that the NyKK-5 had no observable added value to children's numeracy gains beyond the PD that covered children's numeracy alone.



Note. Panel A: by condition; Panel B: by mathematics engagement.

Figure 1: Mean PENS-B Growth by Condition and Mathematics Engagement

Teachers' Classroom Practice

Teacher Logs. From the teacher log data, we computed the proportion of days each teacher reported engaging in PD-related activities (i.e., total number of days out of 78 days total). On average, teachers in the NyKK-5 condition engaged in 48.5 days of PD-related activity (62.2%), teachers in the theory condition engaged in 50.5 days (64.7%), and teachers in the comparison

condition 46.5 days (59.6%). The teachers' self-reported engagement in PD-related activities appeared largely similar across all three conditions.

Next, we examined the specific numeracy skills teachers in the NyKK-5 and theory conditions targeted. For each teacher in both conditions, we computed the proportion of times each numeracy skill was targeted out of the total number of numeracy skills targeted and then computed average proportions by condition (see Figure 2). As can be observed, the proportion of times the teachers in the NyKK-5 and theory conditions engaged in each type of numeracy skill was comparable. Both groups spent most of their time targeting subitizing, counting, and number knowledge. Similarly, both conditions rarely targeted non-verbal calculation and focused on story problems and part-whole combinations even less so.

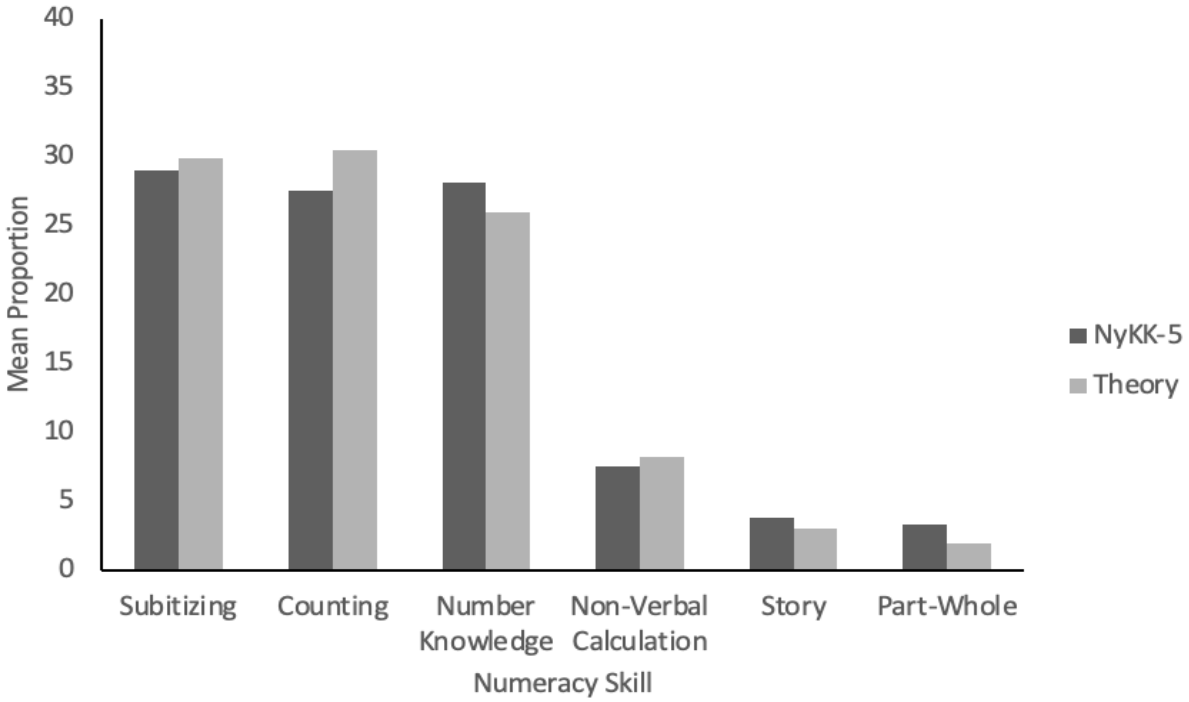
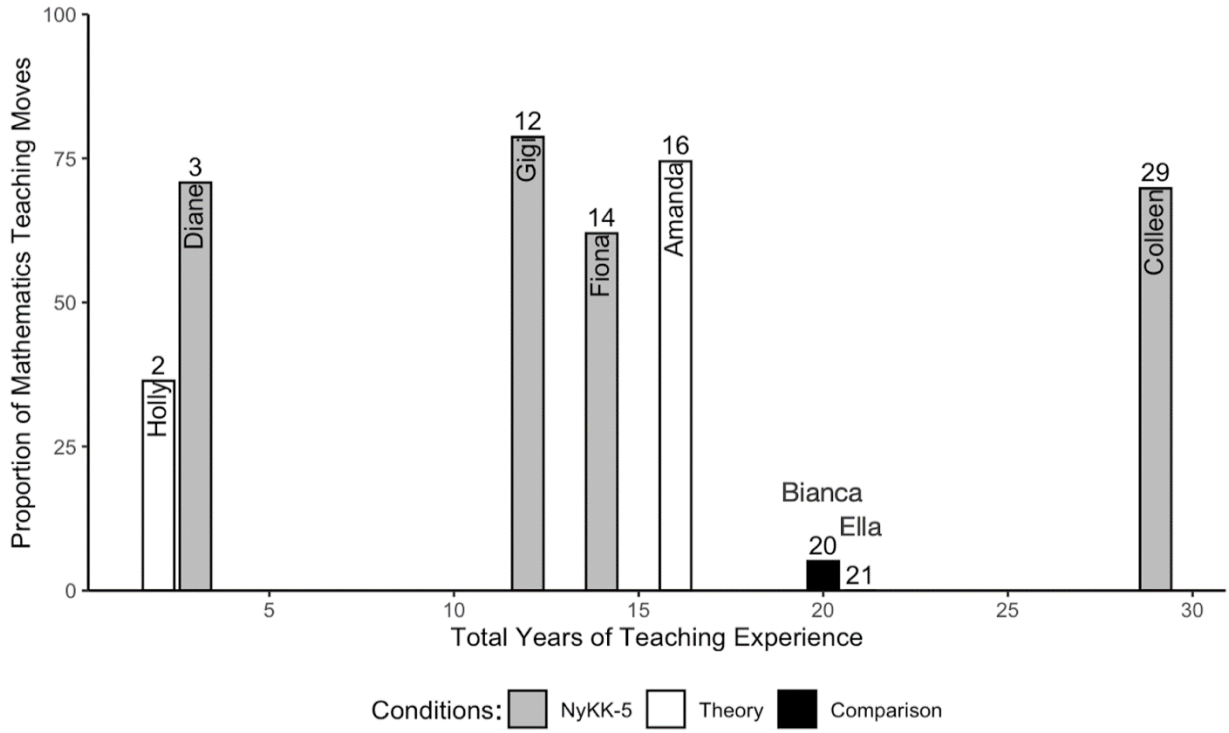


Figure 2: Mean Proportion Teacher Engagement in Each Numeracy Skill by Condition

Classroom Observations. For each teacher, we calculated the proportion of time that each teacher spent engaging in any type of mathematics teaching move out of the total number of behaviors observed across all 12 time-sampling blocks (i.e., 4 blocks x 3 observation sessions). We then regrouped the teachers into three mathematics engagement categories based on the ranges of proportions of mathematics teaching moves out of the total number of moves (math-related and non-math related): high (>50%), moderate (50–25%), and low (<25%) mathematics engagement. Both participants in the comparison condition fell in the low mathematics engagement group (0% and 5%), which was to be expected because the teachers were not introduced to any mathematics-related PD. All participants in the NyKK-5 condition demonstrated high mathematics engagement (62%, 70%, 71%, and 79%). Meanwhile, one participant in the theory condition displayed high mathematics engagement (75%) and the other displayed moderate mathematics engagement (36%).

A one-way ANOVA to test students' numeracy growth revealed a significant effect of mathematics engagement, $F(2,93) = 6.41$, $p = .002$, $\eta^2 = .24$ (see Figure 1, Panel B). Follow-up LSD pairwise comparisons showed that students of teachers with high mathematics engagement and the teacher with moderate mathematics engagement had greater numeracy gains than students of low mathematics engagement teachers, $t(93) = 3.42$, $p < .001$ and $t(93) = 2.52$, $p = .01$, respectively. No differences were observed between the high and moderate engagement groups, $t(93) = 0.10$, $p = .92$. These results indicate that regardless of whether they used the NyKK-5 or not, teachers' level of mathematics engagement in the classroom is related to students' numeracy gains.

Next, we attempted to explain the observed variability in teachers' level of mathematics engagement. Figure 3 presents the observed levels of mathematics engagement for each teacher by number of years of teaching experience and condition. Two important patterns emerge from examining all three variables together. First, across the sample, the level of mathematics engagement was related to the number of years of teaching experience, except in the comparison condition. Second, an examination of the data within condition revealed that all the teachers in the NyKK-5 condition were observed spending over 60% of their classroom interactions with their students on mathematics, despite varying years of teaching experience (i.e., ranging from 3 to 29 years). In contrast, however, a greater variability in mathematics engagement was observed in the theory condition. Specifically, Holly, with two years of experience, displayed a moderate level of engagement, whereas Amanda, with 16 years of experience, displayed a higher level of engagement. Although the sample is too small to draw any definitive conclusions, taken together, these findings may suggest that a tool such as the NyKK-5, designed to simulate in-class PD supports for teachers, could compensate for a lack of teaching experience.



Note. Teacher names are pseudonyms. Ella was in the comparison condition; the proportion of her teaching moves was 0%.

Figure 3: Proportion of Mathematics Engagement by Years of Total Teaching Experience

Discussion

The primary objective of the present study was to assess the impact of a pedagogical tool for teachers, the NyKK-5, on kindergarteners' numeracy development over the course of the school year. We provided professional development to kindergarten teachers on early numeracy with a focus on the development of children's thinking. One group of teachers was provided the NyKK-5 and another was not. The NyKK-5 was designed to simulate the types of in-class supports for teachers that have been identified as critical elements of effective mathematics PD. In particular, the design of the kit and its accompanying PD aimed to support teachers' reflections on their students' learning during the act of teaching (see Gibbons et al., 2017), thereby helping them to connect their newly-acquired knowledge of children's numeracy to their pedagogical actions in real time. In contrast, the teachers without the kit were left to their own devices to make such connections. The teacher logs and observational data generated a description of what was happening in the teachers' classrooms, which was then used to uncover potential explanations for any condition effects.

Contrary to our expectations, we found that the students in the classrooms of the teachers who used the NyKK-5 improved to the same extent as those whose teachers who were not provided the kit. This finding suggests that teachers' knowledge of children's numeracy, regardless of whether they were provided additional instructional tools for use in the classroom, is related to students' numeracy gains over the course of the kindergarten year. This finding is not new; teachers with knowledge about children's thinking are able to interpret what they know, prepare for common student misconceptions, and make instructional decisions to further support mathematical knowledge, reasoning, and problem solving (Ball et al., 2008; Even & Tirosh, 1995; Jacobs & Empson, 2016).

Regarding the secondary research objective, the teacher data added considerable nuance to this finding. First, despite the same degree of attention to all six numeracy skills in the NyKK-5 and theory classrooms, we found that the level of mathematics engagement varied and was more predictive of students' growth than use of the NyKK-5 by itself. Further, an analysis of the within-condition patterns of mathematics engagement and previous teaching experience suggested that the NyKK-5 may be particularly helpful for certain teachers, such as those with less teaching experience. This finding contributes to research in mathematics teacher education by raising the possibility that pedagogical tools over and above knowledge about how children's numeracy develops – and in particular, tools that are situated in practice and encourage teachers' reflection on their pedagogical actions (Grossman & McDonald, 2008) – may be useful under certain conditions but perhaps not all. More specifically, although the small sample precludes definitive conclusions, even teachers with relatively little teaching experience were able to leverage the NyKK-5 to maximize their mathematics engagement in the classroom. Without the tool, the teacher with only two years of experience had little to help her connect her newly-learned knowledge about children's thinking to her classroom practice, something for which the more-experienced teacher was able to compensate (Schoen et al., 2019).

Despite the correlational nature of the analyses and the small sample, the present study has implications for continued research in teacher education. An important implication is that a

pedagogical tool for use in the classroom that serves as a proxy for *in situ* supports for teachers, such as the NyKK-5, may be an effective way to support teachers who experience barriers in engaging students in mathematics, such as a lack of experience. A replication with a larger sample of teachers and a randomized design is thus an important consideration for further investigation. Other teacher individual differences that may account for the variance in students' numeracy growth, such as their knowledge of mathematics itself (Oppermann et al., 2016) and level of confidence in their ability to teach numeracy in the early years (Hadley & Dorward, 2011; Ramirez et al., 2018), should also be examined in future studies.

References

Aunola, K., Leskinen, E., Lerkkanen, M.-K., & Nurmi, J.-E. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology*, *96*(4), 699–713. https://doi.org/10.1037/0022-0663.96.4.699

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3–32). Jossey-Bass.

Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education, 60*(5), 497–511. https://doi.org/10.1177/0022487109348479

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Borko, H., Jacobs, J., & Koellner, K. (2010). Contemporary approaches to teacher professional development. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International Encyclopedia of Education* (3rd ed., pp. 548–556). Elsevier. https://doi.org/10.1016/B978-0-08-044894-7.00654-0

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C. P., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal*, *26*(4), 499–531. https://doi.org/10.2307/1162862

Even, R., & Tirosh, D. (1995). Subject-matter knowledge and knowledge about students as sources of teacher presentations of the subject-matter. *Educational Studies in Mathematics*, *29*(1), 1–20. https://doi.org/10.1007/BF01273897

Ghousseini, H., & Sleep, L. (2011). Making practice studyable. *ZDM: The International Journal on Mathematics Education*, *43*(1), 147–160. https://doi.org/10.1007/s11858-010-0280-7

Gibbons, L. K., Kazemi, E., Hintz, A., & Hartmann, E. (2017). Teacher time out: Educators learning together in and through practice. *NCSM Journal of Mathematics Education Leadership*, *18*(2), 28-46. Retrieved from https://tedd.org/wp-content/uploads/2017/05/JMEL-2017-Teacher-Time-Out.pdf

Ginsburg, H. P., & Ertle, B. (2008). Knowing the mathematics in early childhood mathematics. In O. N. Saracho & B. Spodek (Eds.), *Contemporary perspectives on mathematics in early childhood education* (pp. 45–66). Information Age.

Ginsburg, H. P., Lee, J. S., & Boyd, J. S. (2008). Mathematics education for young children: What it is and how to promote it. *Social Policy Report*, *22*(1), 1–24. https://doi.org/10.1002/j.2379-3988.2008.tb00054.x

Grossman, P., & McDonald, M. (2008). Back to the future: Directions for research in teaching and teacher education. *American Educational Research Journal, 45*(1), 184–205. https://doi.org/10.3102/0002831207312906

Hadley, K. M., & Dorward, J. (2011). The relationship among elementary teachers' mathematics anxiety, mathematics instructional practices, and student mathematics achievement. *Journal of Curriculum & Instruction*, *5*(2), 27–44. https://doi.org/10.3776/joci.2011.v5n2p27-44

Hawes, Z., Merkley, R., Stager, C. L., & Ansari, D. (2021). Integrating numerical cognition research and mathematics education to strengthen the teaching and learning of early number. *British Journal of Educational Psychology*, *91*(4), 1073–1109. https://doi.org/10.1111/bjep.12421

Hiebert, J., & Morris, A. K. (2012). Teaching, rather than teachers, as a path toward improving classroom instruction. *Journal of teacher Education*, *63*(2), 92–102. https://doi.org/10.1177/0022487111428328

Hugo, S. (2016). *365 things to do with LEGO bricks: Lego fun every day of the year*. DK Children.

Jacobs, V. R., & Empson, S. B. (2016). Responding to children's mathematical thinking in the moment: An emerging framework of teaching moves. *ZDM Mathematics Education*, *48*(1–2), 185–197. https://doi.org/10.1007/s11858-015-0717-0

Jordan, N. C., Glutting, J., & Ramineni, C. (2010). The importance of number sense to mathematics achievement in first and third grades. *Learning and Individual Differences*, *20*(2), 82–88. https://doi.org/10.1016/j.lindif.2009.07.004

Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting first-grade math achievement from developmental number sense trajectories. *Learning Disabilities Research & Practice*, *22*(1), 36–46. https://doi.org/10.1111/j.1540-5826.2007.00229.x

Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology*, *45*(3), 850–867. https://doi.org/10.1037/a0014939

Levin, J. R., Serlin, R. C., & Seaman, M. A. (1994). A controlled, powerful multiple-comparison strategy for several situations. *Psychological Bulletin*, *115*(1), 153–159. https://doi.org/10.1037/0033-2909.115.1.153

McDonald, M., Kazemi, E., & Kavanagh, S. S. (2013). Core practices and pedagogies of teacher education: A call for a common language and collective activity. *Journal of Teacher Education*, *64*(5), 378–386. https://doi.org/10.1177/0022487113493807

Navarro, J. I., Aguilar, M., Marchena, E., Ruiz, G., Menacho, I., & Van Luit, J. E. (2012). Longitudinal study of low and high achievers in early mathematics. *British Journal of Educational Psychology*, *82*(1), 28–41. https://doi.org/10.1111/j.2044-8279.2011.02043.x

Oppermann, E., Anders, Y., & Hachfeld, A. (2016). The influence of preschool teachers' content knowledge and mathematical ability beliefs on their sensitivity to mathematics in children's play. *Teaching and Teacher Education*, *58*, 174-184. https://doi.org/10.1016/j.tate.2016.05.004

Presser, A. L., Clements, M., Ginsburg, H., & Ertle, B. (2015). Big math for little kids: The effectiveness of a preschool and kindergarten mathematics curriculum. *Early Education and Development*, *26*(3), 399–426. https://doi.org/10.1080/10409289.2015.994451

Purpura, D. J., Reid, E. E., Eiland, M. D., & Baroody, A. J. (2015). Using a brief preschool early numeracy skills screener to identify young children with mathematics difficulties. *School Psychology Review*, *44*(1), 41–59. https://doi.org/10.17105/SPR44-1.41-59

Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist, 53*(3), 145–164. https://doi.org/10.1080/00461520.2018.1447384

Schoen, R. C., LaVenia, M., Chicken, E., Razzouk, R., & Kisa, Z. (2019). Increasing secondary-level teachers' knowledge in statistics and probability: Results from a randomized controlled trial of a professional development program. *Cogent Education*, *6*(1), 1613799. https://doi.org/10.1080/2331186X.2019.1613799

Stahnke, R., Schueler, S., & Roesken-Winter, B. (2016). Teachers' perception, interpretation, and decision-making: A systematic review of empirical mathematics education research. *ZDM Mathematics Education*, *48*(1–2), 1–27. https://doi.org/10.1007/s11858-016-0775-y

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly*, *19*(1), 99–120. https://doi.org/10.1016/j.ecresq.2004.01.002