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The Effects of Different Pedagogical Approaches on the Learning of Length Measurement in Kindergarten

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Abstract This research investigated the effects of different pedagogical approaches on the learning of length measurement in kindergarten children. Specifically examined were the pedagogical approaches of guided instruction, center-based learning, and free exploration in the context of a play-based learning environment. This mixed design research was implemented in three different classrooms—with one classroom functioning as a control setting. Results suggest that neither guided instruction nor center-based approaches influenced learning more so than free exploration. Older children did better on the measurement tasks which suggests that age or a developmental progression, rather than the pedagogical approach, is more influential when learning how to measure. More children, regardless of grade, showed a preference for using rulers, albeit the older children were more accurate in their use. Education implications are discussed.

Keywords Center-based · Guided · Instruction · Kindergarten · Measurement

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Introduction

Numerous studies report important cognitive, social (Burchinal et al. 2008; Duncan et al. 2007; Pianta et al. 2009; Pramling Samuelsson and Asplund Carlsson 2008; Romano et al. 2010), and even economic benefits (Alexander and Ignjatovic 2012; Bartik 2009) associated with early learning. Early mathematics learning appears to be particularly advantageous to a child's future success in mathematics (Geary 2013; Jordan et al. 2009; Sasanguie et al. 2012).

Given the robust literature on the benefits of early learning, the province of Ontario, Canada implemented a full-day kindergarten (FDK) program for 4 and 5 year olds starting in 2010 (Ministry of Education 2010; Pascal 2009). Previously, the public education system in the province offered half-day kindergarten programs starting at age five, and free of charge, to parents. The current full-day program is also free of charge and, like its previous version, optional for parents. Formal schooling in this region, as stipulated through legislation, begins at age six or grade 1.

In addition to the changes in the amount of time spent in kindergarten and the age at which children may begin kindergarten, important and noteworthy changes were made to the overall approach to educating young children. A common framework was introduced that included new curriculum guidelines as well as a clear articulation of the pedagogical approaches to early learning. Namely, an important emphasis was placed on play-based learning.

In this research we examined whether differences in pedagogical approaches within the play-based learning environment resulted in different learning outcomes for young children in learning how to measure length. According to the curricular expectations for FDK, children were expected to "measure and compare length… of objects/materials, and the passage of time, using non-standard and standard units, through free exploration, focused exploration, and guided activity" (Ministry of Education 2010, p. 103). While the curriculum expectation specifies three different pedagogical approaches, the extent to which each of these is implemented in a classroom setting is unknown and likely to vary. Some teachers may choose to adhere to one or more approach more fully because of their comfort level based on their teaching abilities related to the topic or teaching more generally (Early et al. 2007; Shechtman et al. 2010).

With this curricular expectation in mind and given that teachers do vary in their approaches to structuring learning in their classrooms—despite, perhaps, having a common philosophical framework of play-based learning guiding their practice—our objective was to examine differences in learning outcomes in measuring length across the three different pedagogical approaches: free exploration, center-based learning (i.e., focused exploration), and guided instruction (i.e., guided activity). Therefore, the research question guiding our work was as follows: *What are the effects of different pedagogical approaches in play-based learning environments on young children's understanding of standard and non-standard measurement of length*?

Evidence from other studies suggests that the type of activities children engage in and even the kinds of language adults use with children positively impacts mathematical achievement—well beyond age five (Clements and Sarama 2007; Dearing et al. 2012; Ferrara et al. 2011; Geary et al. 2013; Hanline et al. 2010; Leeet al. 2013; LeFevre et al. 2009). Consequently, differences in children's understanding would suggest that pedagogical approaches are differentially important in supporting the development of young children's measurement ability. An absence of differences in measurement ability may suggest developmental factors, such as age (or grade) or even number knowledge, may be more influential in learning about measurement.

The research is important in that it provides an opportunity to examine how early mathematics learning occurs within a play-based environment. It provides practical and scholarly contributions to the ways in which early mathematics learning environments might be conceptualized. Additionally, research related to measurement and young children is more limited than, for example, number knowledge; thus, this research also contributes in this way.

Literature Review

Measurement

For the purpose of this research, length measurement is defined as the measurement of linear measures of length represented as the distance between two points either on a two-dimensional plane or on a three dimensional object (Clements 1999; Clements et al. 1997; Godfrey and O'Connor 1995; Stephan et al. 2001; van den Heuvel-Panhuizen and Buys 2005). According to the National Council of Teachers of Mathematics'(NCTM 2000, 2006) pre-K to grade 2 measurement standard, early measurement education and learning should include an understanding of measurable attributes (e.g., length, width, etc.) and the application of appropriate techniques of measurement (e.g., units, tools, unit iteration repetition, common referents, etc.).

Measurement techniques include the use of both non-standard (i.e., feet or hands) or standard units (i.e., rulers) of measurement (Szilágyi et al. 2013; van den Heuvel-Panhuizen and Buys 2005, pp. 17, 25). Measurement tasks can involve precise measurements using various units of measurement (e.g., measure the length of the table top) or the visual perceptual comparison of the relative lengths of two objects to determine which is longer or shorter (e.g., comparing heights, distances, etc.), including using a benchmark to make the comparisons (Joram et al. 2005; Stephan and Clements 2003; Szilágyi et al. 2013). Comparison measurement tasks are proposed to be particularly important for early measurement development (Carey and Steffe 1971; Lehrer 2003).

Predominantly, research related to young children and the measurement of length has focused on children's ability to use standard or non-standard units of measurement. Some propose that young children should first be introduced to non-standard units of measurement (Barrett et al. 2011; Piaget and Inhelder 1967; Piaget et al. 1960; van den Heuvel-Panhuizen and Buys 2005). However, more recent research shows that the majority of young children come to school already knowing how to use rulers and with some understanding of the unit representation on rulers (MacDonald and Lowrie 2011). Recent research suggests that young children show a preference for rulers, yet demonstrate an inconsistent performance when using rulers (Boulton-Lewis et al. 1996; Nunes et al. 1993). Challenges with non-standard units are primarily related to the ability to unit iterate—or repeat a unit of measure to determine the total length (Godfrey and O'Connor 1995; Kamii and Clark 1997; Lehrer 2003).

Play-based Learning

The basic premise of play-based learning is that learning is inevitable when children engage in play (Kotsopoulos and Lee 2014; Pramling Samuelsson and Asplund Carlsson 2008). Through play, children learn about their environment, develop cognitively, discover new information about objects, express creativity, use gross and fine motor skills, and develop important emotional and social skills—particularly when engaging in play with other children (Hirsh-Pasek et al. 2009; Johansson 2004).

Play-based learning is different than free play that a child may engage in while at home or even outdoors in that the learning artifacts that populate the learning setting are deemed to have some relative value in terms of advancing a child's understanding of his/her world (Dietze and Kashin 2012; Kotsopoulos and Lee 2013). In play-based environments, the child has, for the most part, control over the activities s/he engages in while in the setting and these activities may be with other children or even with adults (Pramling Samuelsson and Johansson 2009). According to Pascal (2009), play-based learning "taps into children's individual interests, draws out their emerging capacities, and responds to their sense of inquiry and exploration of their world around them" (p. 25).

Children's play in early learning settings has been found to be very mathematical (Seo and Ginsburg 2004). However, very little of this mathematical play can potentially be attributed to the intentional efforts by teachers. A distinction has been made between *mathematics made playful* and *mathematizing elements of play* (van Oers 1996). Mathematics made playful prioritizes the mathematics through intentionally orchestrated acts of play—such as in centers or through guided instruction. Remarkably, research conducted in early learning settings report that between 1 and 6 % of a child's time is spent on planned mathematical tasks (Early et al. 2005; Perlman and Zhang 2010).

Mathematizing elements of play occurs spontaneously during play with objects that may seemingly be non-mathematical, but then are used to explore mathematical concepts (van Oers 2010). Seo and Ginsburg (2004) suggest that 88 % of children engage in spontaneous mathematical-like tasks during every 15 min of play. The child may not recognize the play as mathematical; thus, mathematizing elements of play often involves an adult who, when observing the child playing, engages with the child to inspire and advance mathematical thinking during the play. That being said, an adult may also not recognize the play as mathematical and this may have important implications for supporting the child's learning by intentionally engaging with the child to advance, support, or assess the child's understanding (Kotsopoulos and Lee 2013). Mathematizing elements of play is different than direct instruction in that the interactions are inspired by the activities of the child (Kotsopoulos and Lee 2014, p. 22).

In summary, play-based learning is predominately child-centered. However, it is important to note, as exemplified in the curricular expectations for measurement outlined earlier, that the play-based learning approach in the jurisdiction included some focused and guided exploration—entirely consistent with mathematics made playful and mathematizing elements of play.

Guided Instruction

Guided instruction is a teacher-centered form of classroom instruction in which written and spoken information is transmitted to the students by the teacher (Schweinhart and Weikart 1988). This practice is based on traditional learning theory and proceeds with the assumption that basic skills are acquired initially through some explicit instruction and/or modelling (Stipek and Byler 2004). The teacher is responsible for determining and initiating instructional activities and subsequently assessing the degree to which the information has been received through assessment practices including testing, observation, interviews, and so forth (Schweinhart and Weikart 1988). Guided instruction proceeds in a way that is predetermined by the teacher based on content and skills that need to be transmitted (Lerkkanen et al. 2012). Proponents of this approach emphasize the importance of basic skill development that is facilitated by guided instruction (Stipek and Bylar 2004). Some research suggests that guided instruction is more effective for learning in that the learning happens faster than it would occur with discovery based learning that might be seen during free exploration or even during center-based instruction (Kirschner et al. 2006).

Center-based Instruction

Center-based learning is based upon a constructivist theory where children's discovery is facilitated through well-designed learning tasks (Clements and Battista 1990; Cobb and Yackel 1996). It is an approach in which teachers seek to facilitate a learning environment that places the child at the center of his/her learning (Stipek and Byler 2004); the approach may also involve social interaction with peers (Bauersfeld 1992; Steffan Marrone et al. 2004). Educators have two important roles in center-based learning. They play an active role in guiding the construction of knowledge within the classroom but they also create opportunities for children to direct their own learning through exploration and experimentation that they design (Stipek and Byler 2004). Centers that are effectively implemented can incorporate the element of choice into student learning as well as the opportunity to work with others in engaging, hands-on activities. A distinct aspect of center-based learning is that knowledge is not explicitly taught to the students, it is learned by them (Bottini and Grossman 2005). While there is still no agreement about the most effective balance between child-centered and teacher-directed teaching practices, early childhood education literature leans towards constructivist, child-centered practices (Lerkkanen et al. 2012).

Method

Participants

Sixty-four child participants ($M_{age} = 59$ months, $SD = 6.4$, *Range* 47–70 months) were recruited from one elementary school. The 64 participants were from three kindergarten classrooms. No children in the three kindergarten classrooms were excluded from the study, either by their parents or because of developmental or language issues. Each classroom included junior kindergarten children (JK; age 4) and senior kindergarten children (SK; age 5). Based on school demographic data, the school setting was in a medium socio-economic status community.

Each of the classroom teachers in these classrooms also agreed to participate. Each teacher had been teaching a minimum of five years and each teacher had at least two university degrees. Teachers had also received board-level training on the new FDK program. The three classrooms that participated in our study followed a play-based philosophy. Predominantly, children self-selected their own activities through their day. Small group, as well as whole group instruction was observed in each of these classrooms—albeit infrequently and very briefly when these instances did occur (approximately 10 min or less according to the teachers). Centers were common but children self-selected across the centers and children were less routinely directed to centers. At the time of the data collection, detailed shortly, no focused efforts using any pedagogical approach where observed to be used to facilitate the learning of length measurement in any of the three classrooms.

The three classrooms were randomly assigned to a condition: guided instruction, center-based learning, or the control classroom which was taken to represent the free exploration. The guided instruction class consisted of 19 child (10 boys, 9 girls) participants. Out of the 19 children 10 were JK students and 9 were SK students. The center-based learning classroom consisted of 23 child (11 boys, 12 girls) participants. Out of the 23 children 12 were JK students and 11 were SK students. The control classroom consisted of 22 child (11 boys, 11 girls) participants. Out of the 22 children, 9 were JK students and 13 were SK students.

Materials and Procedures

This research is a mixed design—comparing treatment A (guided instruction), treatment B (center-based learning), to a control classroom (free exploration). For the guided-instruction condition, three short guided-instruction lessons were conducted in one class. Two measurement centers were established in the center-based learning condition. A third class functioned as a control group where no specific activities were introduced intentionally. In both treatment conditions, learning activities were designed to facilitate the use and coordination of multiple representations of units (both non-standard and standard), engage in arbitrary use of units, and engage in comparison tasks (Barrett et al. 2011; Clements 1999; Kamii and Clark 1997; Stephan and Clements 2003; van den Heuvel-Panhuizen and Buys 2005).

The second and fourth authors developed the learning activities used in the guided instruction and the center-based learning. In the guided-instruction setting, the second author taught these lessons. At the time of the data collection, the second and fourth authors were teacher education candidates in these classrooms and they were in the classroom for a period of one academic year. They had been in the classroom for almost 4 months when the data collection took place. The children were all tested on measures described shortly within 2 weeks following the intervention. The teacher education candidates, along with the first author, also assisted with the data collection and the analysis. While this may be perceived as a limitation of the design, our own view was that the highly integrated role of the teacher education candidates in all aspects of the research was a strength of this research and was reflective of the realities of practitioner-based research (Jaworski 2006).

Guided Instruction Condition

There were three guided-instruction lessons conducted with the whole class over three consecutive days.

Lesson 1 Children were asked to create a worm using modelling clay. They were then asked to measure their worms using 12 cm sticks—indicating the number of stick lengths of their worm. After the children completed the task, measurement techniques were demonstrated (e.g., measure from one end to the other, no gaps, then count the units) as a whole class. Next, children measured their worm with small artificial gems approximately 3 cm in diameter, which is another form of non-standard units. Finally, children engaged in a discussion about why measurements differed between the two different non-standard units. The purpose of this lesson was to engage in non-standard units of measurement, comparison, and unit iteration.

Lesson 2 Children were introduced to 30 cm rulers. The use and the features of the ruler were reviewed. Children were then encouraged to measure different items in the room. These measurements were discussed and reviewed.

The purpose of this lesson was to introduce standard units of measurement.

Lesson 3 The concept of using body parts to measure was introduced as well as the 100 cm measuring stick (i.e., meter stick). Children were asked to determine whether their height was taller or shorter than the meter stick. They were then given a meter stick and encouraged to find objects that were shorter, taller or the same size. The purpose of this lesson was to engage in non-standard units of measurement, standard units, and comparison of lengths.

Center-based Learning Condition

There were two centers established in the classroom. The centers were made available to the children over three consecutive days. All children circulated through the centers—either by their own initiative or by the suggestion of the adults in the room.

Center 1 A series of one-dimensional paper sailboats were taped vertically on to a wall. Children were asked to measure their height in terms of total number of sailboats. The purpose of this center was to engage children in non-standard units of measurement.

Center 2 Measuring tapes were provided in the block building center in the classroom. When in the center, teachers would engage the children by asking them specific measurement questions about their structures. For example, children were asked about the materials that they were working with or the artifact that they were creating in terms of whether or not certain components were longer than others (i.e., "How many blocks long is your structure?", "Can you use the measuring tape to measure?"). The purpose of this center was to engage children in standard units of measure and comparison of lengths.

Measurement Task

Children were provided with a sheet of 27.9 × 43.2 cm paper with a T photocopied on it, placed inverted in front of them. Both lines of the T were 20 cm long. Children were asked to pick one of the units of measure available to them to determine which line was longer. Adapted from procedures used by Kamii and Clark (1997), children were given the option of measuring with standard (a 30 cm primary age metric ruler partitioned off in decades) or non-standard units [5 or 12 blocks (each 2 cm by 2 cm by 2 cm)].

If children picked the blocks, first five blocks were provided to check for their ability to engage in unit iteration. Children could use one or all five blocks. If they were unable to use the five blocks to measure, they were then provided with an additional seven blocks and asked if they were then able to measure. Children could opt to use unit iteration or tiling (i.e., lining up a row of blocks end-to-end) across the length of the line using a sufficient number of blocks (Lehrer 2003). The length of the line in non-standard units was ten blocks long. Next, they were asked to measure using the alternative unit of measurement (i.e., unit blocks if ruler was chosen).

Coding categories for this task were adapted from those used by Boulton-Lewis et al. (1996). These coding categorizations were used by Boulton and colleagues to analyze young children's strategies and use of devices for length measurement with a similar task to that used by Kamii and Clark (1997). We coded unit preference (i.e., standard or non-standard), correct unit iteration [i.e., successful or unsuccessful use of device(s)], and whether no measurement was undertaken by the child. Our analysis explores gender, between-grade differences, and between treatment differences.

Results

The majority of children in the three classroom conditions, guided instruction (58 %), center-based learning (69 %), and the control classroom (82 %), selected standard units as their preferred tool to measure length (see Table 1 for the breakdown of frequency and percent of unit preference for each classroom by grade). Overall, 65 % of children in JK and 76 % of children in SK selected standard units when given the option.

All children in all three classroom conditions except for one were unable to measure with five unit blocks; therefore, all children (including the one that could measure with five unit blocks) were presented with twelve blocks. Across the three classrooms, and despite selecting rulers more often as their measurement tool of choice, more children measured correctly with non-standard units compared to standard units. Forty-eight percent of children in JK and 85 % of children in SK measured correctly using non-standard units, by using a tiling method as opposed to unit iteration (e.g., Lehrer 2003). In contrast, 19 % of

Table 1 Total frequencies and percentages of unit preference by classroom and grade

Classroom	Tool	Unit Preference		Total
		JK	SK	
Guided	Non-standard	5 (26 %)	3 (16 %)	8 (42 %)
	Standard	5 (26 %)	6 (32 %)	11 (58 %)
Center	Non-standard	2 (9 %)	5 (22 %)	7 (31 %)
	Standard	10 (43 %)	6 (26 %)	16 (69 %)
Control	Non-standard	4 (18 %)	0	4 (18 %)
	Standard	5 (23 %)	13 (59 %)	18 (82 %)

Table 2 Total frequencies and percentages of measurement ability of non-standard and standard units by classroom and grade

Classroom	Tool	Correct		Incorrect	
		JK	SK	JK	SK
Guided	Non-standard	4 (21 %)	8 (42 %)	6 (32 %)	1 (5 %)
	Standard	1 (5 %)	4 (21 %)	9 (48 %)	5 (26 %)
Center	Non-standard	6 (26 %)	9 (39 %)	6 (26 %)	2 (9 %)
	Standard	4 (17 %)	7 (31 %)	8 (35 %)	4 (17 %)
Control	Non-standard	5 (23 %)	11 (50 %)	4 (18 %)	2 (9 %)
	Standard	1 (5 %)	6 (27 %)	8 (36 %)	7 (32 %)

children in JK and 52 % of children in SK measured correctly using standard units. In both cases, using either standard or non-standard units, more children in SK measured correctly compared to children in JK (see Table 2 for the breakdown of frequency and percent of measurement accuracy for each classroom by grade).

Examining the results per classroom a similar pattern was found given that more children across each classroom measured correctly with non-standard units compared to standard units. In terms of children in each classroom that measured correctly using non-standard units, the results are as follows: guided instruction 63 %, center-based learning 65 %, and control classroom 73 %. For measuring correctly with standard units the results are as follows: guided instruction 26 %, center-based learning 48 %, and control classroom 32 %. Consequently, grade, or age to be more specific, appears to be a more important factor when it comes to learning about length measurement in kindergarten over pedagogical approaches.

Measurement with Non-standard Units

We examined whether there would be differences in ability to measure length between the three classroom conditions, the two kindergarten grades, and gender. A 3 (classroom condition: guided instruction, center-based learning, and control) × 2 (grade: JK vs SK) × 2 (gender: female vs male) analysis of variance (ANOVA) was conducted with measuring length with non-standard units as the dependent variable.

Our analysis shows that the only significant main effect was grade [$F(1, 52) = 9.310$, $p = .004$, $\eta^2 = .152$], thus indicating that children in SK ($M = 0.85$, $SD = 0.364$) outperformed children in JK ($M = 0.48$, $SD = 0.508$) when measuring length with non-standard units. There was no significant main effect of classroom condition [$F(2, 52) = 0.065$, $p = .937$, $\eta^2 = .002$]. Children in the guided instruction, center-based learning, and control classroom did not differ in their ability to measure length with non-standard units, nor was the main effect of gender significant [$F(1, 52) = 0.117$, $p = .773$, $\eta^2 = .002$].

Thus, boys and girls did not differ in their ability to measure length with non-standard units. None of the interactions (class condition × grade, class condition × gender, grade × gender, class condition × grade × gender) were significant. These findings suggest that children's ability to measure length with non-standard units was not affected by classroom conditions or gender; however, grade did have an impact, with children in SK performing better.

Measurement with Standard Units

Another 3 (classroom condition: guided instruction, center-based learning, and control) × 2 (grade: JK vs SK) × 2 (gender: female vs male) ANOVA was conducted with measuring length with standard units as the dependent variable.

The same results were found as with non-standard units. Despite more children measuring correctly with a rule in the center-based classroom, the ANOVA revealed that there was only a significant main effect of grade [$F(1, 52) = 7.519$, $p = .008$, $\eta^2 = .126$], thus indicating that SKs ($M = 0.52$, $SD = 0.508$) outperformed JKs ($M = 0.19$, $SD = 0.402$) when measuring length with standard units. There was no significant main effect of classroom condition [$F(2, 52) = 0.756$, $p = .474$, $\eta^2 = .028$], nor was there a significant main effect of gender [$F(1, 52) = 0.013$, $p = .910$, $\eta^2 = .000$]; thus indicating there were no differences in ability to measure length with standard units between the three classroom conditions or between boys and girls. None of the interactions (class condition × grade, class condition × gender, grade × gender, class condition × grade × gender) were significant.

Parallel to non-standard units, these results reveal that grade was the only variable that impacted children's ability to measure length with standard units, with the SKs outperforming the JKs. The pedagogical approach based on the classroom condition did not matter for children in JK or SK or boys or girls in terms of their ability to measure length with standard or non-standard units.

Discussion

In this research we examined young children's ability to measure using non-standard and standard units following exposure to one of three different pedagogical approaches—namely, guided instruction, center-based learning, and free exploration. Our results show that differences in pedagogical approaches did not have an effect on kindergarten children's understanding of measurement. Many of the children did manage to measure correctly with either standard or non-standard units, and showed a preference for use of ruler. Unit iteration appeared to be problematic for all the children given that no child was able to measure accurately when presented with fewer blocks than was necessary to tile the length of the line they were asked to measure. A grade effect was observed in that the SK children outperformed the younger JK children.

Overall, the three teachers in this research provided the children in their classes with similar learning environments. The classrooms were child-centered with very little guided instruction. While there was center-based learning evident in all three settings, children most often self-selected the center they visited throughout the day. Accordingly, exploring the learning potential of different pedagogical strategies was an important endeavor; albeit, this is also a limitation of this research in that the children may simply have been unaccustomed to guided instruction or focused center-based learning.

Evidence from other studies suggests that very little purposeful time is spent intentionally on mathematics in early childhood education (Early et al. 2005; Perlman and Zhang 2010). The same could be said for the classes in this research. Centers were used in all three classrooms but the extent to which the centers explicitly focused on mathematizing elements of play appeared to be limited. Moreover, there was very little intentional direction of the children to specific centers outside of our own efforts in this research. Nevertheless, studies show that young children's play is often mathematical (Seo and Ginsburg 2004). Consequently, it appears that the spontaneous and sometimes not obvious mathematical play of the children appear to be self-supporting the development of length measurement even more so than the pedagogical approach given the grade effect we observed. It may also be that many of the children come to school with some level of knowledge of measurement from their prior experiences in other early learning settings or in their homes and this forms the basis for their ongoing learning (MacDonald and Lowrie 2011).

Numerous studies point to challenges children face with both unit iteration and non-standard units (Godfrey and O'Connor 1995; Kamii and Clark 1997; Lehrer 2003). Unit iteration has been shown to be particularly challenging for young children and our results support these findings (Kamii and Clark 1997; Lehrer 2003; van den Heuvel-Panhuizen and Buys 2005). Even rulers continue to be problematic for young children (Boulton-Lewis et al. 1996). The documented challenges with measurement, coupled with our results, lead us to suggest that play without any explicit pedagogical intent or teaching may be insufficient to develop some of these concepts that children appear to be ready to be learning. Clearly, the grade effect is showing that something is happening in terms of learning emerging from the play of the children. The more persistent question is whether this is enough learning or whether the level of learning achieved by these or other children can be enhanced.

Conclusion

Young children come to school with knowledge of length measurement. It appears that this knowledge grows over time in a play-based setting. Given that the differences in pedagogical approaches did not yield different outcomes, but rather grade or age did, the factors that contribute to this growth in understanding are uncertain but yet important to uncover through further research. It may be that other mathematical knowledge emerging out of the play context (e.g., number knowledge) is contributing to the children's development of length measurement.

One clear recommendation from this research is the inclusion of more specific and targeted learning of ruler use in kindergarten. The use of rulers presents a prime example. Children want to use the ruler and many appear ready to use the ruler. Yet, without some explanation on how to use the ruler, they continue to make errors in their use. Simply playing with or exposure to rulers appears to be insufficient. Additional research is also needed to explore whether more explicit instruction on rulers from the start of JK enhances learning of length measurement but also with number knowledge which would seem to be intrinsically linked to being able to use a ruler accurately. Finally, teachers should be encouraged to think more deeply about mathematizing elements of play and also about making mathematics more playful (van Oers 2003, 2010). This may also result in greater learning of mathematical concepts for young children—more so than is currently happening largely through self-selection and chance.

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