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Investigating RightStart Mathematics Kindergarten Instruction in Finland

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ABSTRACT: This study investigated the effects of RightStart Mathematics instruction on Finnish kindergartners' mathematics performance. The RightStart group (n = 38) received instruction that followed the RightStart Mathematics program, replacing their typical mathematics instruction, from their kindergarten teachers during the kindergarten year. A comparison group (n = 32) received business-as-usual Finnish mathematics instruction. Early mathematics skills (i.e., counting, number comparison, and addition facts knowledge) significantly improved in both groups during the kindergarten year. No statistically significant difference was found in early mathematics performance between the groups after the instruction phase. The counting skills of initially low-performing children improved in both groups to the level of typically performing children. In first grade, six months after the kindergarten instruction ended, no statistically significant difference was found in mathematics performance between the RightStart and comparison groups. The results are discussed in the context of need and possibilities of educational support.

Keywords: *core instruction, kindergarten mathematics, low-performing children*

Introduction

Internationally and in Finland, there has been a need for legal and practical actions to develop educational support in order to meet the growing diversity in children's learning support needs (Gersten & Newman-Gonchar, 2011; Finnish Ministry of Education, 2007). The educational support system in several countries is operationalized on three tiers: general support, intensified support, and special support (e.g., Gersten, Beckmann, et al., 2009). An assumption in the three-tier model is that the first-level support, general education, is valid and relevant. Along with implementing the

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three-tier model of support, there have been growing demands to provide educators instructional materials and programs that are evidence-based. Regarding early mathematics education in Finland, only a few mathematics programs have been developed based on research in mathematics development, and empirically evaluated (Aunio, Hautamäki, & Van Luit, 2005; Mattinen, Räsänen, Hannula, & Lehtinen, 2010). None has focused on first-tier core instruction. In this study, we were interested in how effective the originally American RightStart Mathematics kindergarten core instruction program is compared to typical Finnish kindergarten mathematics core instruction, in order to support the learning of early mathematical skills. We followed children's mathematics performance during kindergarten and up to first grade.

Early mathematics instruction

During the early childhood years, children develop several mathematical skills such as subitizing (i.e., instantly seeing how many with small quantities), verbal and object counting, and early addition and subtraction that form the foundation for later mathematics learning at school (for a detailed description of learning trajectories, see Sarama and Clements, 2009). Recent research has emphasized the association between early and later mathematics performance from the viewpoint of predictive (e.g., Aubrey, Dahl, & Godfrey, 2006; Aunio & Niemivirta, 2010; Jordan, Glutting, & Ramineni, 2010) and developmental growth (e.g., Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Morgan, Farkas, & Wu, 2009). Children who begin with good mathematics skills seem to perform well later on, but children with weak skills often remain low performers throughout their school career (e.g., Aubrey et al., 2006; Morgan et al., 2009). Moreover, the gap separating low-performing children from average-performing children can even increase during the school years (e.g., Aunola et al., 2004).

Traditionally, early childhood education mathematics instruction has been informal, and thus, most learning happens unguided during playtime or games (Clarke, Doabler, et al., 2011). Moreover, the objectives of early mathematics learning (e.g., set in the kindergarten core curriculum) are often narrow and less structured compared to those in primary grades, in most Western countries. Based on individual interviews assessing children's number knowledge (e.g., number word sequences, number recognition, and object counting) (Sarama & Clements, 2009; Wright, 1991), for many children, kindergarten mathematics provides little challenge and no new content to be learnt, as children are introduced to concepts and skills they are already familiar with. The studies with young Finnish children demonstrate that there is a wide variation in early mathematics performance (e.g., in number sequences forward and backwards, enumeration skills, and mathematics relational skills) among kindergartners and first graders measured as paper-and-pencil tasks (Mononen & Aunio, 2013; Mononen, Aunio, Hotulainen, & Ketonen, 2013). In the beginning of the school year,

> there is a small group of children with significantly weaker skills compared to their peers, as well as children who already know most of the content to be taught in kindergarten or first grade. In educational practice this means that some of the children wait at least half of the academic year until there will be something new to be learnt.

Researchers have suggested that effective early mathematics core instruction can serve as the first approach (i.e., general support) for improving the mathematics performance of kindergarten children, including those at risk for low performance in mathematics (Clarke, Doabler, et al., 2011). Core instruction is built around the most critical mathematics content, and reflects what is currently known about effective instructional design features for enhancing the mathematics performance of low-performing children (Baker, Gersten, & Lee, 2002*;* Clarke, Doabler, et al., 2011; Codding, Hilt-Panahon, Panahon, & Benson, 2009; Gersten, Chard, et al., 2009; Kroesbergen & Van Luit, 2003). Accordingly, core instruction often includes explicit and systematic instruction (i.e., modeling or demonstrating how to solve a problem by using specific procedures, breaking tasks into smaller units, providing a cumulative review, and providing error correction procedures; Bryant, Roberts, Bryant, & DiAndreth-Elkins, 2011) and use of visual representations (e.g., cubes, drawings, 10 frames and number lines) of mathematics ideas at the concrete-representational-abstract levels (Witzel, Mink, & Riccomini, 2011).

Evidence from effective core kindergarten mathematics instruction that applies these characteristics of core instruction has been provided mainly in the United States (e.g., Chard et al., 2008; Clarke, Smolkowski, et al., 2011), and such investigations are lacking in Finland.

The Finnish context

In Finland, participation in kindergarten education (i.e., instruction for six-year-olds, a year before the beginning of formal schooling) is voluntary, but almost full enrollment (99.4% in 2009, Finnish National Board of Education, here after FNBE) is recorded. Finnish kindergarten education is given in conjunction with public schools or day care centers. No accountability demands (e.g., external standardized high-stakes tests) exist in Finnish education system (Sahlberg, 2010). The kindergarten guidelines for curriculum provided by the FNBE (2000) specify the aims of kindergarten mathematics on a very general level. According to the curriculum guidelines, children should have meaningful experiences of mathematics concepts, such as classification, seriation, comparison, and quantities, mainly through play, stories, songs, physical exercise, and discussions along with representational material. Kindergarten teachers are free to choose their teaching materials and methods. Several publishing houses provide kindergarten mathematics teaching materials, which are based on the objectives of the national core curriculum. Typically, these materials (e.g., Takala & Tienhaara, 2009) include topics of teaching mathematics relational concepts such as comparison and classification, number word sequences, enumeration with the numbers 0–10, measurement, and geometry.

Mathematics programs in this study

RightStart Mathematics

In this study, we used a translated version of the *RightStart Mathematics Kindergarten* (RS) core curriculum program (Cotter, 2001), which was the outcome of Cotter's dissertation work (1996). Today, the program has material covering all primary grades (www.rightstartmath.com). International comparison studies had shown that American children at that time did not perform well in mathematics, which stimulated Cotter to develop a new mathematics program. Cotter was inspired by the way mathematics was taught successfully in Japan. Cotter's research (1996) with first graders showed promising signs of the program's effectiveness compared to typical American mathematics instruction. The first grade program shares the main ideas with the kindergarten program: all number work is based around numbers five and ten, minimizing counting one-by-one; transparent base-10 number-naming is used; and children are introduced to ones, tens, hundreds, and thousands with supporting manipulatives (e.g., abacus and overlapping place value cards). In the end of the first grade, compared to the children in a control group, the children who had received RS instruction showed better understanding of multi-digit concept of numbers. For instance, more children ($p < .01$) in the RS instruction group saw 14 as 1 ten and 4 ones when asked to subtract 48 - 14 with base-ten blocks, or they preferred to construct numbers (11, 13, 28, 30, and 42) canonically with tens and ones rather than with all ones. The RS program was chosen for this study as it was research-based and included instructional features not found in typical Finnish kindergarten mathematics programs, such as transparent number naming, emphasizing non-counting strategies, and systematic use of manipulatives.

In the kindergarten program, learning to name numbers is based on the transparent base-10 number-naming system (e.g., 14 is ten-4, 23 is 2-ten 3), and then followed by learning the English number-naming system. This transparent number-naming system used in the RS program has been shown to positively affect the learning of mathematics skills, compared to the Western irregular number-naming system (Miura & Okamoto, 2003). Second, the program emphasizes non-counting strategies in object counting. Subitizing skills are encouraged in counting small quantities (1–4) by saying the total quantity instead of counting one by one. In addition, groupings of fives and 10s are used. For example, the number seven is first taught as "five and two" and demonstrated in beads of two different colors on an abacus (e.g., five blue and two yellow beads), or 9 + 4 is calculated by changing the amount to 10 + 3 on an abacus. For the most part, the RS program focuses on manipulating numbers in the range from 0 to 20. However, children are introduced to numbers up to 1000 (i.e., place value knowledge), too, with supporting manipulatives, as well as for calculations with 10s and 1s with the help of an abacus (e.g., 30 + 30, 44 + 1 or 57 + 2).

Most of the activities include games or working with manipulatives. In activities, all children have access to manipulatives: Abacuses based on groupings of five and 10 beads with two colors (also known as Slavonic abacuses), number and quantity cards, base-10 cards, tiles, and tally sticks are regularly used throughout the program. In addition, concrete, representational, and abstract levels in representation are apparent. A new concept is practiced with a concrete manipulative (e.g., showing a quantity of five with tally sticks or on abacus), then followed by representational material (e.g., quantity of five as tally marks on a card), and finally practiced as an abstract representation (e.g., number symbol of five on a card). Written work with numbers (i.e., worksheets) is postponed until a child has understood the mathematic concept. A teacher has similar manipulatives as children, but in a bigger format (e.g., a large abacus) to aid teaching.

There are 77 lesson plans in the RS kindergarten manual. One lesson is composed of a short warm-up activity (usually practicing different types of number word sequences, subitizing, or days of the week) and from three to six activities (e.g., teacher-guided or pair activities with manipulatives or card games) around one or two learning objectives. In learning, understanding is highly emphasized, not learning by rote. The role of the teacher is to encourage thinking by asking questions and having discussions with children, not only giving answers. The activities are supposed to be done following the order given in the manual, as one activity may require skills taught in the previous activity. Instructions for the activities are specific, including questions to be asked by the teacher.

Finnish mathematics instruction

Kindergarten of The Little Forest (KLF) (Wäre et al., 2009a, 2009b) instruction material, which follows the national core curriculum mathematics guidelines (FNBE, 2000), was used as a comparison program. One of the most frequently used kindergarten materials in Finland, the KLF was chosen by the kindergarten teachers in this study. In addition to mathematics, this material includes lessons for science and early reading, so that all three skill areas are covered under the same changing theme (such as autumn or space and time). The teacher's manual provides specific instructions for each activity. In addition to whole-group mathematics activities, small-group activities such as board games are often used. Most of the activities are teacher guided; however, children are encouraged to investigate and discuss on mathematics topics. Many of the activities are supported by using manipulatives (e.g., cubes and dot or number cards), and the children have activity books.

The main differences between the two programs, RS and KLF, are that the RS program emphasizes more non-counting strategies, presents quantities based on groupings of five and 10, applies transparent number naming and uses specific manipulatives, such as abacuses, systematically throughout the program. The key objectives of both programs are presented in Table 1.

The aim of the study

The main purpose of this study was to investigate the effects of the RightStart Mathematics program on kindergartners' learning of early mathematics skills compared to typical Finnish kindergarten mathematics core instruction. The main research question was: What kind of mathematical performance do children, who receive either RS or KLF core instruction, demonstrate during the kindergarten year? In addition to comparisons between the two groups (i.e., all children), we focused on children who initially performed low in early mathematics skills. All children's mathematics performance was followed to the first grade in order to see the maintenance effect of kindergarten instruction. Finally, we were interested in how the kindergarten teachers experienced using the programs.

TABLE 1 Key Objectives of the RightStart and the Kindergarten of the Little Forest Programs According to the Manuals

RightStart Mathematics Kindergarten	**Kindergarten of the Little Forest**
Numeration	*Classification and seriation*
Can count out 31 objects and arrange in groups of tens	With object and pictures
Can recognize quantities 1 to 100 and represent them on abacus	*Number word-quantity-symbol relations*
Knows even numbers to 20	In the number range 1-20
Knows odd numbers to 19	*Odd and even numbers*
Can count by twos to 30	*Number word sequences*
Can count by fives to 100	Forward and backwards, in the number range 0-20
Can count by tens to 100	*Comparison (more, less, equal)*
Money	With quantities and numbers in the number range 0-20
Knows name and value of penny, nickel, and dime (or value of coins of cents and euro in the Finnish version)	*Addition and subtraction*
Place value	Partition numbers 1-10 into parts
Knows 10 ones is 1 ten	*Problem solving*
Knows 10 tens is 1 hundred	Addition and subtraction word problems
Knows, for example, 37 as 3-ten 7	*Introduction to place value 20-100*
Addition	*Measurement (with nonstandard measure)*
Understands addition as combining parts to form whole	Length and Mass
Can partition numbers 3 to 10 into parts	*Geometry*
Knows number combinations equal to 10	Circle, square, triangle, symmetry
Knows number combinations up to 10	*Time*
Subtraction	Clock (hour)
Understands subtraction as missing addend	Days of the week
Understands subtraction as separating	Months of the year
Problem solving	*Introduction to money (euros)*
Can solve addition problems	
Can solve missing addend problems	
Can solve basic subtraction problems	
Geometry	
Knows mathematical names of triangle, rectangle, and circle	
Knows parallel and perpendicular lines	
Can continue a pattern on the geoboard	
Time	
Knows days of the week	
Knows months of the year	
Can tell time to the hour	
Can tell time to the half hour	
Measurement	
Can determine length with nonstandard measure	
Fractions	
Can divide into halves and fourths	
Knows unit fractions up to 1/16	

Method

Participants

Six kindergarten teachers were recruited from one in-service training course (Developing Early Mathematics Skills) taught by the second author. Participation in this study was voluntary. All kindergarten teachers were female, qualified kindergarten teachers and had years of teaching experience (ranging from two to 10 years). Three teachers were willing to start using the RS program with their kindergarten group in the following fall (i.e., the RS group). Three other teachers wanted to follow the typical kindergarten mathematics program (i.e., KLF group), which they would have used despite the study.

In the beginning of the study, there were 82 children in the kindergarten classrooms. The number of children participating at the Time 1 (in September) and Time 2 (in May) assessments, and included in the analyses, was 70 (43 boys and 27 girls, M_{age} = 74.4 months, *SD* = 3.48, age range 69–81 months). Attrition from data analysis was due to excluding children who had inadequate Finnish skills to participate in assessments, who were absent at Time 2, or who moved to another city during the study. Of the children, 38 were in the RS group (22 boys and 16 girls, M_{age} = 74.6 months, *SD* = 3.75) and 32 in the KLF group (21 boys and 11 girls, M_{age} = 74.2 months, *SD* = 3.18). Six children from the RS group and three children from the KLF group were absent at Time 3 (Grade 1), and were therefore excluded from the Time 3 analysis. All children had written permission from their parents as well as municipalities' educational authorities to participate in the study. Typically, children are expected to participate in mathematics instruction in kindergarten. During this study, the mathematics instruction appeared for children similar to their normal activities in kindergarten. In assessment sessions, it was agreed with the assessors beforehand that if children would feel the assessment session uncomfortable, the assessor should stop the session and try another time, if possible. The words 'assessment' or 'test' were not used when talking with the children.

The kindergarten groups came from three cities in southern Finland. One RS group and one KLF group were located in day care centers; both groups had two teachers per group due to the large number of children (more than 20) in the group. Having two teachers enabled the group to be divided into two smaller groups, for instance, during literacy and mathematics instruction. One RS group and one KLF group were in local public schools, and had smaller groups (fewer than 20 children) with one teacher.

In addition to examining the effects of the instruction among all children in the RS and KLF groups, we classified the sample as mathematically typically performing (TYP) and low-performing (LOW) based on the children's performance on the Early Numeracy Test (ENT: Van Luit, Van de Rijt, & Aunio, 2006) at Time 1 (see the ENT description in the Measures section). We used the minus one standard deviation of the mean score (from our sample) as the cut-off point for low performance. The mean score, 29.61, in our sample was close to the mean score, 30.22, of 78-month-old children in Finnish normed data (Aunio, Hautamäki, Heiskari, & Van Luit, 2006). There was a total of 13 LOW children, of whom six (two boys and four girls) were in the RS group and seven (three boys and four girls) in the KLF group. Among the TYP children (n = 57), 32 (20 boys and 12 girls) were in the RS group and 25 (18 boys and 7 girls) in the KLF group.

Measures

Cognitive skills

We assessed non-verbal reasoning skills and receptive vocabulary to estimate the children's other cognitive skills, in addition to mathematics, before the instruction phase. *Raven's Coloured Progressive Matrices* (Raven, 1965) was used individually to measure the children's non-verbal reasoning. There are 36 items on the test. On each test item, the child is asked to identify the missing element from multiple choices that completes a pattern. One point is given for a correct answer. The reliability, in terms of Cronbach's coefficient alpha with 95% confidence interval ($CI_{0.95}$), was .77 ($CI_{0.95}$ = .69–.84) in this data. Receptive vocabulary was assessed individually with *The Peabody Picture Vocabulary Test - Revised* (PPVT-R, Dunn and Dunn, 1981), using a shortened version adapted in Finnish (Lerkkanen et al., 2010). On each test item (a total of two practice and 30 test items), there are four pictures to a page. The examiner states a word that describes one of the pictures and asks the child to point to the picture that the word describes. One point is given for a correct answer. The Cronbach's alpha in this data was .53 ($CI_{0.95}$ = .35–.68).

Mathematics skills

Various mathematics measures were used to evaluate the effectiveness of the instruction. In the kindergarten year, *The Early Numeracy Test* (Van Luit et al., 2006) was used. This test is based on a developmental view of children's number sense and has been used in several countries (e.g., van de Rijt et al., 2003). There are 40 items, and each item is scored either zero for a wrong answer or one for a correct answer. The two scales on the ENT can be distinguished: one measures relational skills and one counting skills (Aunio & Niemivirta, 2010). The relational scale includes 20 items that measure comparison, classification, one-to-one correspondence, and seriation abilities, and the counting scale comprises 20 items that require the ability to use number words, structured counting, resultative counting, and general understanding of numbers. The Finnish standardization study of ENT (Aunio et al., 2006) demonstrated excellent validity and reliability in terms of Cronbach's coefficient alpha for the whole scale, .90 ($CI_{0.95}$ = .88–.91). In terms of validity evidence about demographic variables, the Finnish standardization study reported small gender differences favoring girls on performance in relational and whole scales. Mothers' and fathers' professional level had a small positive impact on children's performance in whole scale. The domicile had a small effect, the children in small towns and rural areas did perform better than the children in metropolitan area. There was no effect of the birth order of the children, or the family form. The number of children in the family had an effect, the children from families with two or three children did better than other children. In the current study, Cronbach's alpha for the whole scale was .79 ($CI_{0.95}$ = .72–.86), for the relational scale .60 ($CI_{0.95}$ = .44–.72), and for the counting scale .75 ($CI_{0.95}$ = .65–.82).

The Basic Addition Fluency Test (Salminen et al., 2008) was used to measure children's early addition skills individually in kindergarten. There are 45 addition facts with numbers 1–5 presented horizontally in the test papers. The examiner shows a child one fact at a time and asks the child to give the answer to the problem. The test is time-limited (3 minutes), and one point is given for the correct answer.

BANUCA (BAsic NUmerical and Calculation Abilities; Räsänen, 2005) is a standardized test that measures the basic numerical and calculation skills of children aged seven to nine years old. The tasks are paper-and-pencil tasks and can be performed individually or with groups of children. Five of the BANUCA's subscales were used in the study. The four subscales not included (magnitude comparison, quantity-number symbol relations, number sequences increased by one, addition and subtraction calculations with numbers up to hundreds) had ceiling or floor effects based on normed data, and were thus not used. The number comparison scale was used in all assessment time points (Times 1–3), and the four other subscales (addition, subtraction, number words, and arithmetical reasoning) only at Time 3. *The number comparison scale* aims to assess understanding of the base-10 system. The scale includes ten items. For each item, the child has to identify the largest of the four numbers by drawing a cross over the number. The five first items are from the number span 1–60, and the last (tenth) item includes a comparison with thousands. There is a 4-minute time limit to complete the scale. One point is given for a correct answer. The Cronbach's alpha in this sample at Time 1 was .65 ($CI_{0.95}$ = .51–.76). For *the addition scale*, the child has to write an answer to eight addition facts with the numbers 1–10 presented horizontally. Half of the items include carrying over 10. There is a 4-minute time limit to complete the scale. *The subtraction* *scale* is similar to the addition scale. In the scale, the child has to write an answer to eight subtraction facts with numbers 1–15 presented horizontally. Half of the items include numbers over 10, and three carrying over 10. There is a 4-minute time limit to complete the scale. *The number words scale* assesses knowledge of spoken and written numbers and the base-10 system. There are eight items on the scale. The examiner says a number word, which is one of the numbers in a row of five numbers. The child has to identify the correct number within 20 seconds, by drawing a cross over the number. The four first items are from the number span of 1–80, and the last (eighth) item includes numbers of ten thousands. One point is given for the correct answer. On *the arithmetic reasoning scale*, a child sees a number pattern of three numbers (e.g., 2, 4, 6). The child has to identify which number of the four alternative numbers given will continue the number sequence (e.g., 5, 8, 7, 10). There are 15 items on the scale on the number span 1–100. There is an 8-minute time limit for completing the scale. The maximum score for the entire BANUCA scale is 49. The Cronbach's alpha for the whole scale in this sample was .88 ($CI_{0.95}$ = .84–.92).

Kindergarten teachers' feedback concerning the instruction

The kindergarten teachers of the RS groups were asked to fill out a structured logbook sheet for every lesson taught. This provided feedback from the lessons taught and the activities accomplished (see Gresham, MacMillan, Beebe-Frankenberger, & Bocian, 2000 for indirect assessment methods of treatment integrity). The functionality of every task in the lesson was assessed (1 = not good, 2 = good, 3 = very good, or x = not completed). On the same logbook sheet, the motivation of the teacher and the children (from teacher's point of view) was evaluated, on a scale ranging from 4 (poor) to 10 (excellent), a common assessment scale used in Finnish schools. Every logbook sheet also had space for comments. The teachers in the KLF groups were asked to fill out a questionnaire about the mathematics content taught during the kindergarten year, based on the teaching objectives in the manual used. In addition, a questionnaire with structured and open questions was collected from all teachers concerning implementation of and satisfaction with the program used during the kindergarten year.

Procedure

Translation of the RS material

We were given permission by the author of the RS program to translate the material into Finnish and to use the material in our study. The Finnish version included 87 lessons; for practical reasons, we divided some of the two-hour lessons into two one-hour lessons. Furthermore, some cultural aspects affected the translation work. For example, compared to English, Finnish has a structured number naming system with the following exceptions: teen numbers (inverted naming), the currency used is the euro instead of the dollar (for example, quarters are not used as coins), and a 24-hour clock is used instead of a 12-hour clock. Otherwise, the content of the manual and the tasks was kept as similar to the original as possible. The translation was checked by a multilanguage team of researchers.

Data collection

The Time 1 assessment took place at the beginning of the kindergarten year (from mid-August to mid-September 2009) and the Time 2 assessment in May 2010, at the end of the kindergarten year. The Time 3 assessment was carried out in first grade in December 2010. The cognitive skill assessments were conducted only at the Time 1 assessment as individual interviews and took between 15 and 20 minutes. The children's mathematical skills at Time 1 (ENT whole scale, number comparison, and addition fluency) and at Time 2 (ENT counting scale, number comparison, and addition fluency) were assessed in individual interviews, which took 30–40 minutes. The ENT relational scale was not used at Time 2, as most of the items are too easy for children more than 6.5 years old (Aunio et al., 2006). The Time 1 and 2 assessments were conducted in a quiet room in the kindergarten by a trained research assistant, teachers familiar with the tests, or the first author. The Time 3 assessment (BANUCA) was conducted in the first-grade classroom groups by the first author, and took between 30 and 40 minutes. The tasks were presented in the following order: addition, number comparison, subtraction, number words, and arithmetical reasoning.

Instruction in the RS group

Before the instruction phase, the teachers in the RS group were briefly introduced to the RS program by the first author and provided with a translated teacher's manual and the manipulatives (such as abacuses, tiles, number and dot cards, etc.) required for implementing the program. The teachers were advised to contact the first author, if needed, during the year. Teachers sent the completed logbook sheets every other month to the first author.

The teachers were advised to follow the order of the tasks in the program manual and to conduct a lesson three times a week, replacing their typical mathematics instruction, each lesson lasting about 30–45 minutes, in order to cover most of the lessons. Several months after the instruction phase began, we noticed that due to kindergarten constraints, the teachers were not able to keep up with the intended pace, but were conducting approximately two sessions of 30–45 minutes per week. The sessions were held in groups of 14–16 children.

Instruction in the KLF group

The teachers in the KLF group were asked to implement their typical mathematics instruction throughout the kindergarten year. Both groups followed the same kindergarten instruction material, KLF. The sessions were held in groups of 13–16 children. In Finnish kindergarten, there is no set time frame for the mathematics lessons that should be covered during a week. The teachers reported spending approximately 45–75 minutes per week on mathematics activities. These activities included specific learning sessions focused only on mathematics but also shorter activities such as math-related songs and stories during the morning circle time.

In the first grade, children in both groups were mixed in different classrooms with new teachers. Each group used published mathematics instruction material that followed the national curriculum mathematics objectives (FNBE, 2004).

Data analysis

The comparability of the RS and KLF groups was checked related to the age and cognitive and mathematics performance of the children at Time 1, using separate ANOVA tests. The instruction effectiveness from Time 1 to Time 2 within and between the RS and KLF groups was analyzed as performance growth, using separate ANOVAs. Then, we compared the performance of the RS and KLF groups at Time 3. Similar analyses were conducted for the LOW groups (RS_{low} and KLF_{low}). We examined whether the LOW children reduced the performance gap with the TYP children after instruction at Time 2 and Time 3, using ANOVAs with post hoc comparisons. In all multiple comparisons using ANOVAs, a Bonferroni-adjusted correction for Type I error was applied. Non-parametric analyses (the Wilcoxon rank-sum test or the Kruskal-Wallis test) were also conducted when the performance of small samples was compared, but if these analyses did not change the pattern of significance in the findings, we decided to report only the results from the parametric analysis.

Effect sizes were calculated for the mathematics outcome measures, using Hedges' *g* with correction for small sample sizes (see Turner & Bernard, 2006). Hedges' *g* was calculated as the difference between the mean Time 1–Time 2 change in the RS group and the mean Time 1–Time 2 change in the KLF group, divided by the Time 1 pooled within-group standard deviation (*SD*) (Morris, 2008). At Time 3, the mean score of the RS group and the mean score of the KLF group were divided by the Time 3 pooled within-groups *SD*. The confidence intervals (95%) for the effect sizes were calculated by using the standard error of the effect size estimates (Turner & Bernard, 2006).

Results

Comparisons between the RS and KLF groups

Performance at Time 1

Comparing the equivalency of the RS and KLF groups at Time 1 showed no significant difference between the groups in age, $F(1,68) = 0.29$, $p = .595$, or on any cognitive and mathematics measures. Table 2 provides the means, standard deviations, and statistical significances for the Time 1 measures.

TABLE 2 Means, Standard Deviations, and Statistical Significances by Groups at Time 1

	RS group			KLF group				
Scale	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	F^a	*p*
Raven (max 36 p.)	35	21.57	(4.33)	31	19.77	(4.57)	2.69	*ns.*
PPVT-R (max 30 p.)	35	18.23	(3.46)	31	18.61	(2.99)	0.23	*ns.*
ENT Whole (max 40 p.)	38	29.05	(5.18)	32	30.28	(5.44)	0.93	*ns.*
ENT Relational (max 20 p.)	38	16.89	(2.37)	32	16.97	(2.07)	0.12	*ns.*
ENT Counting (max 20 p.)	38	12.16	(3.58)	32	13.31	(4.01)	1.62	*ns.*
Comparison (max 10 p.)	38	5.37	(1.90)	32	6.09	(1.84)	2.62	*ns.*
Addition (max 45 p.)	38	16.39	(8.93)	32	19.38	(11.19)	1.54	*ns.*

Note. [a] Degrees of freedom (1.64) in Raven and PPVT-R, and (1.68) in all other scales.

Instruction effectiveness from Time 1 to Time 2

Repeated analyses of ANOVA showed that the performance of both groups improved statistically significantly between Time 1 and Time 2 on all measured mathematics scales (Table 3). Comparison of the gain scores from Time 1 to Time 2 showed no statistically significant differences between the RS and KLF groups on any mathematics scales (Table 3). Accordingly, the mathematics scores of both groups had improved similarly regardless of the type of kindergarten mathematics program used.

TABLE 3 Means, Standard Deviations, Statistical Significances, and Effect Sizes of Gain Scores by Groups

	RS group (*n* = 38)		KLF group (*n* = 32)				
Scale	*M*	*(SD)*	*M*	*(SD)*	*F*(1,68)	*p*	*ES*[a]
ENT Counting	3.53***	(3.26)	2.50***	(3.01)	1.85	*ns.*	.27 [-.20, .74]
Comparison	1.89***	(1.80)	1.28***	(1.85)	1.97	*ns.*	.32 [-.15, .79]
Addition	11.21***	(9.01)	12.28***	(7.88)	0.28	*ns.*	-.11 [-.57, .36]

Note. [a] *ES* = effect size as Hedges' *g*, with a 95% confidence interval. *** indicates a statistically significant ($p < .001$) improvement within the group.

Performance at Time 3

At Time 3 in first grade, no performance differences on the BANUCA were found between the RS and KLF groups (Table 4).

TABLE 4 Means, Standard Deviations, Statistical Significances, and Effect Sizes by Groups at Time 3

	RS group (*n* = 32)		KLF group (*n* = 29)				
Scale	*M*	*(SD)*	*M*	*(SD)*	*F*(1,59)	*p*	*ES*[a]
BANUCA (max. 49 p.)	37.38	(6.43)	38.34	(6.98)	0.32	*ns.*	-.14 [-.64, .36]

Note. [a] *ES* = effect size as Hedges' *g*, with a 95% confidence interval.

Low-performing children

To see how the low-performing (RS_{low} and KLF_{low}) children benefited from the kindergarten mathematics core instruction and how did they perform in first grade, similar analyses were applied as in comparing the RS and the KLF groups. We were also interested in whether the LOW children would be able to catch up to the typically performing (TYP) children by the end of kindergarten or in first grade.

Performance at Time 1

Comparing the LOW and TYP children across the sample, the ANOVA test revealed that the TYP children (M_{age} = 74.88, SD = 3.38) were older than the LOW children (M_{age} = 72.31, SD = 3.28), $F(1,68) = 6.20$, $p < .05$. The RS_{low} and KLF_{low} groups did not differ in their age, $F(1,11) = 0.27$, $p > .05$, or in cognitive and mathematics measures at Time1 (Table 5).

ANOVA post hoc comparisons with Bonferroni-adjusted correction revealed that compared to the TYP groups, the only statistically significant difference ($p < .05$) in cognitive measures was found in Raven between the KLF_{low} group and RS_{typ} group, favoring the RS_{typ} group (Table 5). As expected, both LOW groups performed statistically significantly ($p < .05$) weaker than the TYP groups on all mathematics scales (Table 5), except for number comparison scale. Using age as a covariate did not change these results.

TABLE 5 Means, Standard Deviations for the LOW and TYP Groups at Time 1

	RS_{low} group			KLF_{low} group			RS_{typ} group			KLF_{typ} group		
Scale	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
Raven (max 36 p.)	5	18.40	(3.36)	6	16.33	(4.08)	30	22.10	(4.29)	25	20.60	(4.35)
PPVT-R (max 30 p.)	5	15.80	(1.48)	6	18.00	(4.15)	30	18.63	(3.54)	25	18.76	(2.73)
ENT Whole (max 40 p.)	6	20.17	(3.92)	7	22.00	(2.65)	32	30.72	(3.38)	25	32.60	(3.29)
ENT Relational (max 20 p.)	6	13.33	(2.42)	7	14.86	(1.86)	32	17.56	(1.68)	25	17.56	(1.73)
ENT Counting (max 20 p.)	6	6.83	(2.04)	7	7.14	(2.12)	32	13.16	(2.85)	25	15.04	(2.34)
Comparison (max 10 p.)	6	3.83	(1.33)	7	4.86	(1.35)	32	5.66	(1.86)	25	6.44	(1.83)
Addition (max 45 p.)	6	6.67	(5.92)	7	7.86	(5.49)	32	18.22	(8.23)	25	22.60	(10.23)

Instruction effectiveness from Time 1 to Time 2

Repeated measures of ANOVA showed that the performance of both groups (RS_{low} and KLF_{low}) had improved ($p < .05$) statistically significantly between Time 1 and Time 2 on the ENT counting and addition scales (Table 6). Comparing the gain scores from Time 1 to Time 2, no statistically significant differences between the RS_{low} and KLF_{low} groups were found on any mathematics scales (Table 6). Accordingly, the mathematics scores of both groups had improved similarly regardless of the type of kindergarten mathematics program used.

TABLE 6 Means, Standard Deviations, Statistical Significances, and Effect Sizes of Gain Scores for the LOW Groups

	RS_{low} group (n = 6)		KLF_{low} group (n = 7)				
Scale	*M*	*(SD)*	*M*	*(SD)*	F(1,11)	p	*ES*[a]
ENT Counting	6.50*	(4.04)	6.14*	(2.91)	0.03	*ns.*	.16 [-.86, 1.18]
Comparison	1.67	(1.51)	1.00	(2.31)	0.36	*ns.*	.47 [-.57, 1.50]
Addition	13.33*	(7.17)	9.00*	(6.68)	1.27	*ns.*	.71 [-.34, 1.76]

Note. [a] *ES* = effect size as Hedges' g, with a 95% confidence interval. * indicates a statistically significant ($p < .05$) improvement within the group.

At Time 2, ANOVA post hoc comparisons with Bonferroni-adjusted correction revealed that RS_{low} group performed on the ENT counting scale at the same level ($p > .05$) as both TYP groups (Table 7). The Kruskal-Wallis test with the pairwise comparison revealed a non-significant difference ($p > .05$) on the ENT counting scale also between the KLF_{low} and both TYP groups. On the number comparison scale, the RS_{low} group performed significantly lower compared to both TYP groups ($p < .05$). The KLF_{low} children performed lower than the KLF_{typ} children on the number comparison scale ($p < .05$), but the Kruskal-Wallis test with the pairwise comparison revealed a non-significant difference ($p > .05$). On the addition scale, the RS_{low} children performed statistically significantly weaker than the KLF_{typ} children ($p < .01$), but not compared to the RS_{typ} group. The KLF_{low} performed statistically significantly weaker ($p < .05$) on the addition scale compared to both TYP groups.

TABLE 7 Means, Standard Deviations for the LOW and TYP Groups at Time 2

	RS_{low} group (n = 6)		KLF_{low} group (n = 7)		RS_{typ} group (n = 32)		KLF_{tyo} group (n = 25)	
Scale	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
ENT Counting	13.33	(3.62)	13.29	(3.82)	16.13	(2.65)	16.52	(2.37)
Comparison	5.50	(0.84)	5.86	(2.04)	7.59	(1.72)	7.80	(1.44)
Addition	20.00	(10.28)	16.86	(3.76)	29.03	(11.40)	35.80	(8.55)

Performance at Time 3

At Time 3 in the first grade, no performance differences on the BANUCA were found between the RS_{low} and KLF_{low} groups using ANOVA (Table 8).

TABLE 8 Means, Standard Deviations, Statistical Significances, and Effect Sizes for the LOW Groups at Time 3

	RS_{low} group (n = 6)		KLF_{low} group (n = 7)				
Scale	*M*	*(SD)*	*M*	*(SD)*	F(1,11)	*p*	ES^a
BANUCA (max. 49 p.)	30.00	(2.28)	33.29	(5.02)	2.16	*ns.*	-.76 [-1.82, .29]

Note. [a] *ES* = effect size as Hedges' *g*, with 95% confidence interval.

When the performance of the RS_{low} and KLF_{low} groups were compared to the TYP groups, ANOVA post hoc comparisons with Bonferroni-adjusted correction revealed that the RS_{low} showed weaker performance than the TYP groups ($p < .01$), whereas no statistically significant difference was found between the KLF_{low} and TYP groups ($p > .05$) (Table 9).

TABLE 9 Means, Standard Deviations for the TYP Groups at Time 3

	RS_{typ} group (n = 26)		KLF_{tyo} group (n = 22)	
Scale	*M*	*(SD)*	*M*	*(SD)*
BANUCA (max. 49 p.)	39.08	(5.84)	39.95	(6.81)

Kindergarten teachers' feedback concerning instruction

The RS teachers taught mathematics with the RS program for seven months. According to the logbook information, the number of lessons conducted was nearly half (36 in both groups) of the total number of lessons (87) in the program manual, and the total instruction time was approximately 1620 minutes (36 x 45 minutes). In general, the teachers were satisfied with the functionality of the activities (*M* = 2.70 out of 3.00, *SD* = 0.49) based on the 128 activities evaluated. The teachers and children were well motivated (both *M* = 9.10 out of 10, *SD* = 0.8). The RS program learning objectives not covered during the kindergarten year included counting by fives and 10s, operating with numbers over 20 (place value), some number combinations, money, time, and fractions. Teachers found the program too extensive, including too many activities to be covered during the kindergarten year, although the teachers considered the activities important. Teachers reported that they were pleased with the amount of cumulative review provided in the activities; however, some also argued that there were too many similar activities. Overall, the teachers commented that the instructions in the manual were clearly written and easy to follow and the mathematical concepts hierarchically constructed. The manipulatives and games helped the children learn concepts, and made learning interesting and motivating for the children. All teachers were willing to use the RS program in the following year with another group.

The teachers using the KLF program reported that they had taught almost all mathematic sections in the material during the kindergarten year. The instruction time used for mathematics varied from 45 to 75 minutes per week, which is slightly less than in the RS group. The teachers were satisfied with the material they used.

Discussion

The purpose of this study was to investigate the effects of the RS program on the learning of early mathematics skills of kindergartners, compared to typical Finnish kindergarten mathematics core instruction (the KLF program). The RS program seemed to be as effective as the KLF program. The early mathematics skills (i.e., oral and object counting, number comparison, and addition facts knowledge) of all children improved significantly in kindergarten regardless of the program used. The counting skills of the initially low-performing children in both groups improved to the level of their typically performing peers. In first grade, no difference in mathematics performance was found between the RS and KLF groups.

What could be the reasons for similar results regardless of the program used? Firstly, in our study, all participating teachers had voluntarily attended the same in-service professional developmental course on early mathematics development before our study, the one we recruited them from. Thus, all of our teachers shared a positive attitude and good knowledge of early mathematics building blocks and teaching of mathematics, which have been shown to positively affect children's learning (Ertle et al., 2008; Sarama & Clements, 2009). Secondly, the types of instructional features and content of the programs might have been too similar in order to reveal performance differences between the groups. The instructional features of the RS program (e.g., using non-counting strategies and transparent number-naming system), not often seen in the Finnish kindergarten mathematics programs, seemed to also support children's early mathematics learning. Thirdly, the instruction phase was long in duration. The teachers in the RS group taught for less time than stated in the original manual, due to kindergarten constraints. A structured RS program with 2–3 lessons per week seemed to be too much to implement for kindergarten teachers, who had been used to flexible mathematics instruction. The KLF group provided mathematics teaching and learning during playtime, games, or short activities, as the national curriculum guidelines emphasize. However, the weekly time used in mathematics was almost similar in both groups.

This study provided further evidence that mathematics core instruction can improve the mathematics skills of low-performing kindergartners (Chard et al., 2008; Clarke, Smolkowski, et al., 2011). In this study, the counting skills (both oral and object counting skills) of the low-performing children improved to the level of their typically performing peers. In both programs practicing counting skills was emphasized more than practicing comparison and addition skills. In first grade, the RS_{low} children performed significantly weaker compared to the TYP children on the mathematics assessment, but this difference did not exist between the KLF_{low} children and the TYP children. These results highlight the importance of being continuously aware of the mathematics performance level of the children, and providing them opportunities for slowing down and practicing skills that are challenging (Fuchs, Fuchs, Schumacher, & Seethaler, 2013). If intensified support is needed, instruction programs that are shorter in their duration and more skill targeted may serve as means for boosting early early mathematics skills (e.g. Jordan, Glutting, Dyson, Hassinger-Das, & Irwin, 2012; Siegler & Ramani, 2009). To have strong knowledge and confidence to assess mathematics skills and to teach early mathematics, kindergarten teachers should be provided with high-quality professional development training. One important challenge for scientific work is to find effective instruction programs to use in education, or at least to find features that support the challenged learning of some children.

Limitations and future directions

The major limitation in our study was the small number of participating children, especially in terms of low-performing children. Therefore, the results obtained should be considered with caution. Including only a small number of participants was partly due to our limited resources: long core instruction studies with an adequate sample and a randomized design would be expensive to conduct. As the study was conducted in kindergartens with kindergarten teachers, it added ecological validity to our study (Reed, Sorrells, Cole, & Takakawa, 2013). Volunteered teachers in this study were well-motivated to go through the whole study process, but this may have affected the outcome results to be too positive (Slavin, 2008). Investigating new instructional programs with kindergarten educators will give the researchers valuable information about what kinds of programs are possible to do in kindergarten practice. In future, it would be interesting to examine, how the RS program or other kindergarten mathematics programs work in subpopulations with special educational needs, such as with children having language impairments.

In future studies, observations in classrooms should be included, in addition to teacher-reported logbooks, to provide more information about how in practice teachers implement the program. In addition, the follow-up period after the instruction phase should be more controlled, as this may affect the Time 3 results. For instance, regarding the mathematics program and instruction method used in the classroom, and possible intensified support offered for some children. As children in the RS group seemed to be motivated towards mathematics activities according to their teachers, it might be valuable in future studies to observe and collect data more carefully, whether motivation and interest in mathematics learning in kindergarten has any long term effects on children's mathematics learning outcomes. Furthermore, workshops with professional development tutoring for teachers during the instruction phase would provide sharing experiences with other teachers, and keep up with the intended pace, but might also connect research and practice together more (Haseler, 2008).

Conclusion

The study contributed and showed that RightStart Mathematics and typical Finnish mathematics core instruction improved the mathematics learning (i.e., oral and object counting, number comparison skills, and addition facts knowledge) of kindergartners similarly. In addition, the counting skills of low-performing children improved to the level of their typically performing peers in both groups.

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