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Revisiting an Old Methodology for Teaching Counting, Computation, and Place Value: The Effectiveness of the Finger Calculation Method for At-Risk Children

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Number sense is critical to the development of higher order mathematic abilities. However, some children have difficulty acquiring these fundamental skills and the knowledge base of effective interventions/remediation is relatively limited. Based on emerging neuro-scientific research which has identified the association between finger movement/representation and numerical cognition, this one-year study examined the effectiveness of a finger calculation program for at-risk and non-at-risk school children. Specifically, the study sought to determine the impact of learning Chisanbop (Korean finger calculation method) on the number sense, computational, quantitative concepts, and problem solving skills, as well as attitudes towards mathematics, of children at the grade 2 and grade 5 levels. The findings indicate a significant impact on attitudes for math for at-risk grade 2 students.

Keywords: dyscalculia, math learning-disabled, finger representation, finger calculation, math interventions

Introduction

Number Sense and Numerical Cognition

Number sense, including counting strategies, arithmetic facts, and combinations, is fundamental to the development of more complex mathematical concepts (Gersten & Chard, 1999). There is extensive research to indicate that children must develop automaticity and accuracy of basic facts (Goldman, Pelligrino, & Mertz, 1988; Hasselbring, Goin, & Bransford, 1988), as well as effective computational strategies, before progressing to more advanced mathematical abilities. Girls and boys who have difficulties with these basic skills are at-risk for future math failure (Jordan, Kaplan, Olah, & Locuniak, 2006). There is a need to provide these children with research-based intervention/remediation. However, there is a paucity of research in the area of mathematics (Butterworth, Varma, & Laurillard, 2011; Gersten, Jordan, & Flogo, 2005; Seethaler & Fuchs, 2005; Swain, Bertini, & Coffey, 2010), and in particular, focusing on place value and basic fact attainment (Gersten et al., 2005). Further, the emerging evidence from the field of cognitive neuroscience which connects finger representations and the development of numerical cognition has yet to be extensively

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applied to classroom instructional strategies (Butterworth et al., 2011; Geary, 2010; Moeller, Martignon, Engel, & Nuerk, 2011).

Children with learning disabilities, and specifically developmental dyscalculia, are most likely to experience repeated failure at learning place value and having automaticity of basic facts (Geary, Hoard, & Bailey, 2012; Maccini, Mulcahy, & Wilson, 2007). The prevalence rates of children with dyscalculia in North America is approximately 5-8% (Lerner & Johns, 2009; Shalev, 2004), which does not even include the number of children who do not qualify for a clinical diagnosis, but for whom arithmetic and mathematics are extremely challenging. Repeated difficulties with basic math skills can lead to math anxiety, embarrassment over failure, and negative attitudes towards learning mathematics (Ahmed, Minnaert, Kuyper, & van der Werf, 2012; Swaim Griggs, Rimm-Kaufman, Merritt, & Patton, 2013). It is troubling to have students with an aversion to learning mathematics, as it is to have those with weak math ability. Educators in both Canada and the United States have expressed concern about the poor math performance on the Programme for International Student Assessment (PISA) (Froese-Germain, 2010; Peterson, Woessmann, Hanushek, & Lastra-Anadón, 2011). The National Mathematics Advisory Panel Final Report (2008) highlighted the need to focus on effective methods of instruction for children who struggle with mathematics. Even beyond the school years, low numeracy skills are a reason for concern, as Butterworth et al. (2011) point out, costing countries reduced gross domestic product growth, totaling losses of over £2.4 billion in the United Kingdom alone. Therefore, whether for the general school population, children with dyscalculia, or those at-risk for math failure, effective methods for teaching basic and foundational math skills is paramount.

Remedial Strategies

Compared to the vast research and literature about children who have reading and writing difficulties, the knowledge base for identifying and treating girls and boys with math disorders is relatively limited (Fuchs, Fuchs, & Hollenbeck, 2007; Gersten & Jordan, 2005). The last named group is characterized by a lack of understanding basic math concepts and by an inability to routinely perform additions, subtractions, divisions, and multiplications at an age-appropriate level. Prevention/intervention strategies for children who have difficulties calculating range from general instructional principles such as comprehending math vocabulary (Bachor & Crealock, 1986), using cues to discriminate computation signs (Saland, 1990), drawing to represent numbers and operations (Wilson, 2012), direct instruction (Miller & Hudson, 2007), strategy instruction (Hutchinson, 1993), to encouraging students to set their own goals (Fuchs, Bahr, & Rieth, 1989), and the use of technologies (Mastropieri & Scruggs, 1987). In some cases, instructional decisions are based on a „hit-and-miss" approach, where teachers keep trying new methods until the student realizes success.

However, a particular methodology to intervene or remediate math difficulties should not be selected at random or justified by anecdotal evidence or personal beliefs. Instead, decisions regarding the types of approaches to use with struggling learners in order to meet their diverse needs have to be based on sound research findings. Even though the number of studies providing evidence on how to successfully teach reading or spelling outnumbers those studies dealing with effective math instruction, we can still draw on a large body of research telling us what works in helping children with learning problems acquire arithmetic skills. Several relevant meta-analyses have identified key principles necessary for successfully teaching students how to perform addition, subtraction, division, and multiplication (e. g. Gersten, Chard, Jayanthi, Baker, Morphy, & Flojo, 2009; Kroesbergen & van Luit, 2003).

Based on the available information, Fuchs, Fuchs, Powell, Seethaler, Cirino, and Fletcher (2008) list seven principles that need to be considered when providing effective practice: (1) instructional explicitness, (2) instructional design to minimize the learning challenge, (3) strong conceptual basis, (4) drill and practice, (5) cumulative review, (6) motivation to help students regulate their attention and behavior to work hard, as well as (7) ongoing progress monitoring. In order to apply these principles in a constructive way, it is advisable to always consider the particular developmental level of a given child.

Mathematical competence is acquired in stages, from very basic precursor skills to higher-order processing abilities. For example, monitoring the developmental phase in which students start to generate answers to subtraction problems in the course of their elementary school career, one can observe that (a) children first represent the minuend with their fingers and then fold down the number of fingers equal to the subtrahend, (b) they then match the number of fingers of the minuend to the number of fingers of the subtrahend and derive the answer by counting the unmatched fingers that remain, (c) they subsequently count upward from the subtrahend until they reach the minuend (the answer is the number of fingers in the counting sequence) or they count backward from the minuend the number of times equal to the value of the subtrahend (with the last number in the counting sequence being the answer), and (d), in the last substage, they retrieve the answer from long term memory (Jordan, Hanich, & Uberti, 2003). Facility with other essential arithmetic operations is also acquired gradually and progressively, at certain times using the fingers as calculators (ebd.). Thus, finger-counting is not an unwanted phenomenon during the development of mathematical skills in children that parents and teachers should suppress, but a normal and healthy intermediate step on the way to building complex problem solving abilities.

It is not productive to overlook any of the different phases and try to teach a certain skill that antecedes a competence level that a child has not yet sufficiently mastered. Even though a girl or a boy might be able to produce correct responses to a certain kind of math problem, she or he will lack an enhanced understanding of the underlying operations, if the newly taught skill is not built on a solid foundation of preceding concepts that she or he has already acquired. Consequently, math difficulties do not decrease, but eventually intensify (Stein, Kinder, Silbert, & Carnine, 2006).

Finger Counting and Calculations

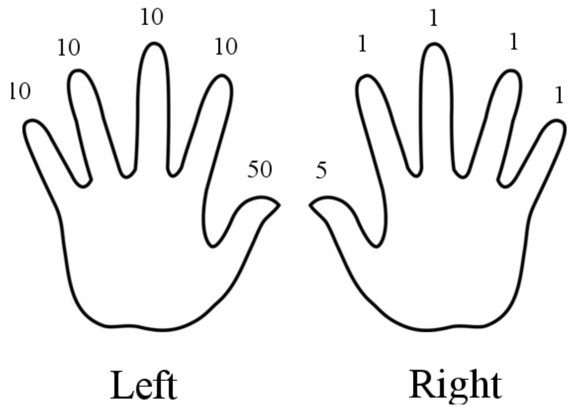
As indicated above, finger-counting plays a functional role in the acquisition of arithmetic concepts during a certain stage of the development (Jordan, Hanich, & Uberti, 2003). Butterworth (1999) has been a pioneer in studying the mathematical brain, identifying regions of it that are associated with number sense, and visual, as well as spatial representations. Since that time, other researchers have explored the neuro-functional link between fingers and number processing (Andres, Seron, and Oivier, 2007; Ansari, 2008; Dehaene & Cohen, 2007; Kaufmann, 2008; Lee & Fong Ng, 2011; OECD, 2003; Penner-Wilger & Anderson, 2013). Andres, Di Luca, and Pesenti (2008) argue that fingers may be the "missing link" in the development of efficient numerical comprehension. Indeed, many elementary school teachers would attest that young children use their fingers, almost instinctively, for counting and computation.

One's fingers can furnish a natural and readily available way to represent numerical information and reflect numerical concepts (Beller & Bender, 2011). They can provide a permanent, visual depiction of the one-to-one principle, leading to the attainment of concepts such as magnitude, interval, and ratio. Since on our hands we represent numbers as a sum or a multiple of 10, our fingers can facilitate the understanding of the 10-base numerical system. Further, the permanency of the representations helps to reduce working memory load when performing numerical calculations. Finger representation becomes a type of "embodied cognition" that supports the internalization of numerical information (Fischer & Brugger, 2011; Ifrah, 2000). Therefore, a remedial approach which incorporates the systematic use of finger representations may prove to be effective for teaching basic number sense concepts such as counting, computation, and place-value during a certain phase in the development of arithmetic abilities.

The use of fingers to represent quantity may take many forms. For example, finger counting may be as simple as raising a finger to represent a count of "1", beginning with the thumb and moving towards the outside of the hand. For some tribes in New Guinea, counting involves the whole body beginning with the little finger of the right hand and ending with the left little finger, touching wrist, elbow, shoulder, eyes, nose, mouth, and ears (Ifrah, 2000).

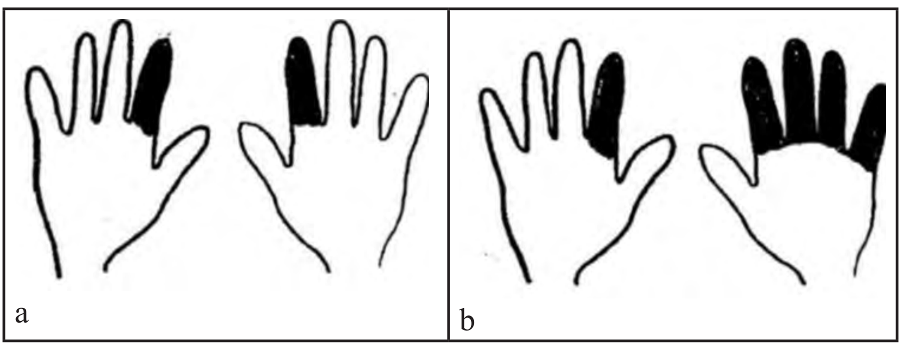
The presumably best-known finger counting technique is called *Chisanbop*. It is an approach developed in Korea in the 1940s and is based on the abacas (base-10 system) (see e. g. Benson, 1981; Knifong & Burton, 1979; Rumiati, & Wright, 2010). The name *Chisanbop* is made up of the Korean words "chi" (for "finger") and "sanbeop" (for "calculation"). Within this system, number values are assigned to each of the fingers. The hands are held in a relaxed posture above a table (palms down). Each finger of the right hand counts as one, except for the thumb, which represents the value of five; each finger of the left hand counts as ten, except for the thumb, which represents the value of fifty (see Figure 1).

Figure 1. **The fingers and their representing values of the left and the right hand**



Counting is done by touching the table with the corresponding fingers, starting with the right index finger. For example, the value of six is represented by pressing the right thumb (for five) and the right index finger (for one) onto the table; the value of 78 is represented by pressing the left thumb (for fifty), the left index and middle finger (for twenty), the right thumb (for five), as well as the right index, middle, and ring finger (for three) onto the table. For illustrative purposes, fingers that touch the table are depicted black in Figure 2. In the first example, the value of eleven is represented; in the second example, it is the value fourteen.

Figure 2. **Two examples of fingers representing two different numbers (11 and 14)**



Using this finger counting system, all values between zero and ninety-nine can be represented. With *Chisanbop*, addition is done by counting-on to the next number. For example, to add 65 and 23, one has to touch the table with her or his left thumb (for fifty) and left index finger (for ten), as well as with her or his right thumb (for five). In a subsequent step, one must, in addition, press her or his left index and middle finger (for twenty), as well as her or his right index, middle, and ring finger (for three) onto the table. Subtractions are performed in a similar way: For example, to subtract 5 from 38, one has to touch the table with her or his left index, middle, and ring finger (for thirty), as well as with her or his right thumb (for five) plus her or his right index, middle, and ring finger (for three). In a subsequent step, one must lift up her or his right thumb (for five) and count the values of the remaining fingers still touching the table. If the numbers exceed 99, one has to use paper and pencil and apply a variation of the standard algorithm. It is beyond the scope of this paper to discuss the exact way addition and subtraction problems with numbers beyond 99 are performed by implementing *Chisanbop*. The same applies to the way, multiplication and division problems are solved. We thus refer the reader to further literature on *Chisanbop* (e. g. Gurau & Lieberthal, 1979; Lieberthal, 1979).

In most school subjects, students are required to retrieve different facts from memory. They are asked to recall the different presidents of the United States of America, to name mandatory attributes of mammals, or to state the Spanish word for "bread". With math, it is different. Here, children have to solve problems by using certain algorithms. Simply remembering facts is not sufficient. Rather, students need to practically apply heuristics to novel problems (Campbell & Xue, 2001). Such tasks usually strain one's working memory to a greater extent than retrieval tasks. Our working memory is very susceptible to falter when we get anxious or nervous (Ashcraft & Krause, 2007). Thus, math anxiety is a common phenomenon among students, whereas "history anxiety" is unheard of. *Chisanbop* may be a good way to provide remedy. Fingers are always available. Children can cling to the *Chisanbop* system and are thus able to keep track of the number words uttered while reciting the counting sequence. This reduces working memory overload. In consequence, being nervous has less of an impact on a child's performance and may influence her or his attitude towards math in a positive way.

The research that does exist on finger calculation methods is limited and dated from the 1980's. Etlinger and Ogletree (1980) had success teaching finger counting to handicapped children, while Ogletree and Chavez (1981) used finger mathematics with low SES (socio-economic status) grade 2 students and found significant improvement in math achievement. Usnick and Engelhardt (1988) confirmed the use of finger calculation for children at-risk for math failure, noting that it is consistent with Piaget's theory of cognitive development. Though *Chisanbop* was introduced to North America in the 1970's, the research on effectiveness is also limited (Dougherty, 1981) and dated. However, existing findings indicate that this approach seems to be beneficial in increasing number sense, basic fact, and place value skills in struggling learners (see above).

Research Questions

In the present paper, we report on a study about the effects of a *Chisanbop* intervention. The experiment ran over the course of a whole school year (ten months) and was part of a larger project within a specific school district in the province of British Columbian (B.C.) in western Canada, involving 2nd grade and 5th grade students. The group that we could draw our sample from thus consisted of children who were in a developmental stage in which finger-counting is still very common and widespread (2nd graders), as well as of children who have largely moved on to more abstract calculating abilities (5th graders). In addition, we had the chance to involve students from both class levels that exhibited rather poor math skills and were at-risk for school failure. As mentioned, the use of fingers as a tool to perform arithmetics commonly happens during an early stage of a child's elementary school career. In later years, students might view such a procedure as embarrassing. As a consequence, their attitudes towards math will probably not get influenced in the same positive way as can be expected for their younger counterparts. Considering the above elaborations on the presumed effects of the finger counting technique in question, our research was guided by the following hypotheses:

1. The *Chisanbop* finger calculation method will result in significant increases concerning number sense, basic fact, and place value skills for 2nd and 5th grade students.
2. Younger children and those at-risk for mathematical failure will especially benefit from this approach regarding the abilities just mentioned.
3. The *Chisanbop* finger calculation method will trigger a significant increase in positive attitudes towards mathematics.
4. Younger children and those at-risk for mathematical failure will experience an especially large boost in attitudes.

Methods

Participants

We were able to recruit two 2nd and two 5th grade teachers to participate in our study on the effectiveness of *Chisanbop*. All of them were involved in the aforementioned larger project on professional development in a specific school district in B. C. They agreed to involve the students in their classes as subjects of our experiment. In the end, our sample consisted of 75 students; 37 attended one of two grade two French Immersion classes (n = 20 and 17, respectively), 42 attended one of two grade five English classes (n = 23 and 19, respectively). Age was similar between the groups at the different grade levels. At the beginning of the study, the average age for the grade two students was 6.85 and 6.93 years, and for the grade five students, it was 9.88 and 9.85 years. Gender was also relatively equally distributed at the grade two level with 9 girls and 11 boys in the first, and 9 girls and 8 boys in the second class. The first of the grade five classes consisted of 13 girls and 9 boys, the second of 8 girls and 11 boys.

All classrooms were representative of both high and low SES areas. Both grade two French Immersion classes were in middle SES communities and composed of mainly Caucasian students. The first grade five class was situated within a low SES community, with a high population of First Nations and East Indian children; the second grade five class was also in a low SES community, in a school with a designated focus on science and math, and had primarily Caucasian children. All teachers followed the standard B. C. mathematics curriculum and used the same textbook series which was prescribed by the school district. None of the teachers had previously utilized a finger calculation instructional strategy.

To compare the impact on the children who struggle the most with arithmetic, we created 'at-risk' groups for each classroom (see below).

Design

Randomization into an experimental and a control group for each class level was not possible. Thus, a quasi-experimental pre-post control group design was applied, with one experimental and one control group at each of grade two French Immersion and grade five English classes. Dependent variables were measured shortly prior and immediately after a 10-month period in which the two experimental classes received instruction in *Chisanbop.*

Intervention

The two experimental group teachers, Fiona and Martin[1], received training in the *Chisanbop* method prior to, and during, the study. Training followed a standard workshop procedure (see Appendix A), as presented by the first author on numerous occasions in the past (based on Calder & Burchby, 1992, and Foothills Academy, n.d.). The experimental teachers met formally twice over the 10-month period with the first author and also corresponded occasionally via email to discuss implementation of the *Chisanbop* method, ideas for games or review activities, and ways to logistically set up the classroom to allow for individualized or small group instruction. In order to enhance treatment fidelity, the first author provided two review sessions during the study and also did two demonstration lessons in each experimental classroom to model direct instruction, use of review activities/games, and workbook follow-up.

After the pre-testing phase, the children in the experimental group received instruction in *Chisanbop* for approximately 20 minutes as part of their daily math lessons, following a format outlined in Calder and Burchby (1992). Each instructional session included direct instruction or review, followed by a cooperative game and/or worksheets designed to reinforce the skill just taught (see Appendix A). Fiona and Martin made weekly journal entries about specific children who were experiencing success or great difficulty with the *Chisanbop* method. During the period of examination, none of the participating students missed school more than 10% of the time.

Instruments

Number sense, basic fact, and place value skills of the children in all classrooms were assessed using three subtests from the *Woodcock-Johnson (WJ) Achievement Test* by Woodcock and Mather (1998): *Computation* (r_{tt} = 0.86), *Quantitative Concepts* (r_{tt} = 0.91), and *Applied Problem Solving* (r_{tt} = 0.93). The WJ is a widely-accepted and nationally normed instrument for determining educational progress in students with mild to moderate cognitive disabilities. Subjects were also assessed for attitudes about mathematics using the *Attitudes Towards Math* subtest (r_{tt} = 0.80), which is part of the *Test of Mathematical Abilities* (TOMA) by Brown and McEntire (1984). The TOMA is an instrument that is applied to identify students who are above or below age peers in five areas of math functioning. In the *Attitudes Towards Math* subtest, children respond to 15 questions such as "It's fun to work math problems" or "My friends like math more than I do" on a four-point scale.

1 Names are pseudonyms.

Various qualitative data were also collected. All joint meetings with Fiona and Martin were audio-taped, and later transcribed. Artifacts included teacher journals, teacher emails, and summary notes of informal teacher meetings. A number of methods were used to enhance the reliability of the findings. In order to triangulate the data, multiple sources were included (such as teacher journal entries, transcripts, student artifacts, and examiner notes made during the pre- and post-assessments). As well, a trained research assistant administered all post-tests, to eliminate any examiner bias. Further, both the standardized assessment tools, WJ and TOMA, have adequate reliability ($r \geq .80$). Finally, the research assistant reviewed qualitative data to verify the themes and patterns generated by the first author. Validity of the findings is enhanced by 1) the use of standardized tests which report adequate content validity scores, 2) treatment within the authentic classroom context, and 3) relative equivalency between mathematics programs at each grade level.

Data analysis

The quantitative data (WJ and TOMA test scores) were analyzed for differences between experimental and control whole class groups, as well as the 'at-risk' groups. We converted all WJ raw scores to z-scores. A number of studies indicate that attitudes towards math influence the long-term performance of children in this subject to a crucial extent (e. g. Duerr, 2013; Rech, 2013). Without having a positive stance in this regard, students are bound to eventually fail. In accordance with common practice in the local school district in which this study was conducted, we used the TOMA test scores as the decisive factor for determining whether a girl or a boy was considered to be at-risk for math failure. In order to also account for the actual calculation skills at the time of our experiment, we added the *Calculations* z-scores to the TOMA scores. Because the *Calculations* z-scores were all in all considerably lower than the TOMA scores, attitudes were still the predominant factor in deciding which students were in need of special support. The lowest 30% were considered to be in danger of failing in math. There were more 'at-risk' students in the grade 2 experimental classroom because three students tied for the last spot in the group.

Because the data does not follow a normal distribution, non-parametric statistical analyses were utilized (Wilcoxon Signed-Rank Test and Mann Whitney *U*). Qualitative evidence related to the research questions were highlighted in transcripts, emails, research notes, and on the test protocols by the first author, following a procedure as outlined by Miles, Huberman, and Saldaña (2014). The purpose of this approach was to identify certain recurring themes or patterns in the data that seem to be representative of what the teachers thought and believed about the usefulness of our finger counting technique, what they found instrumental, and what they struggled with. A trained research assistant reviewed all data for confirming and disconfirming evidence. Any disagreements concerning the data analysis were discussed by the first author and the research assistant until consensus was reached.

Table 1. ***Descriptive Statistics.***

	Class *n*	Class Min.	Class Max.	Class *M (SD)*	At-Risk *n*	At-Risk Min	At-Risk Max.	At-Risk *M (SD)*	Not At-Risk *n*	Not At-Risk Min.	Not At-Risk Max.	Not At-Risk *M (SD)*
Experimental Grade 2												
Age	20	6.10	7.09	6.85 (0.38)	8	6.10	7.05	6.91 (0.33)	12	6.10	7.09	6.80 (0.42)
Calculations (pre)	20	1.2	3.3	1.87 (0.53)	8	1.3	2.2	1.75 (0.30)	12	1.2	3.3	1.94 (0.64)
Applications (pre)	20	1.2	2.6	1.88 (0.42)	8	1.2	2.3	1.81 (0.41)	12	1.4	2.6	1.93 (0.44)
Quantitative Concepts (pre)	20	0.6	3.2	1.85 (0.72)	8	1.4	3.2	2.21 (0.67)	12	0.6	2.5	1.60 (0.66)
Attitude (pre)	19	3.0	14.0	8.63 (3.20)	7	3.0	7.0	5.43 (1.99)	12	7.0	14	10.50 (2.07)
Calculations (post)	19	1.0	4.0	2.58 (0.69)	7	2.0	4.0	2.56 (0.76)	12	1.0	4.0	2.59 (0.68)
Applications (post)	19	2.0	6.0	3.16 (1.06)	7	3.0	4.0	3.46 (0.63)	12	2.0	6.0	2.98 (1.24)
Quantitative Concepts (post)	19	2.0	4.0	2.61 (0.62)	7	2.0	4.0	2.77 (0.77)	12	2.0	3.0	2.52 (0.53)
Attitude (post)	19	4.0	15.0	10.05 (3.05)	7	4.0	12.0	8.29 (3.20)	12	6.0	15.0	11.08 (2.54)
Control Grade 2												
Age	16	6.09	7.10	6.93 (0.33)	4	6.09	7.05	6.80 (0.47)	12	6.10	7.10	6.98 (0.28)
Calculations (pre)	17	1.0	3.8	1.87 (0.79)	5	1.2	1.9	1.44 (0.31)	12	1.0	3.8	2.04 (0.87)
Applications (pre)	17	0.5	4.4	1.97 (0.87)	5	0.5	1.8	1.30 (1.50)	12	1.5	4.4	2.25 (0.84)
Quantitative Concepts (pre)	17	0.6	3.4	1.82 (0.76)	5	0.9	1.7	1.26 (0.35)	12	0.6	3.4	2.06 (0.76)
Attitude (pre)	16	7.0	13.0	9.50 (1.83)	5	7.0	8.0	7.60 (0.55)	11	8.0	13	10.36 (1.50)
Calculations (post)	16	1.0	5.0	2.68 (0.85)	4	2.0	3.0	2.10 (0.62)	12	1.0	5.0	2.88 (0.85)
Applications (post)	16	1.0	6.0	3.71 (1.19)	4	1.0	4.0	2.75 (1.14)	12	3.0	6.0	4.02 (1.06)
Quantitative Concepts (post)	16	1.0	5.0	2.96 (1.04)	4	1.0	3.0	2.05 (0.64)	12	2.0	5.0	3.27 (0.98)
Attitude (post)	16	6.0	14.0	10.00 (2.13)	4	9.0	11.0	10.00 (0.82)	12	6.0	15.0	10.00 (2.45)

Experimental Grade 5												
Age	22	9.09	10.11	9.88 (0.38)	7	9.09	10.08	9.90 (0.36)	15	9.10	10.11	9.88 (0.40)
Calculations (pre)	22	2.2	5.2	3.99 (0.82)	7	2.2	5.0	3.71 (1.08)	15	2.8	5.2	4.11 (0.67)
Applications (pre)	23	2.0	8.0	3.70 (1.37)	7	2.0	4.8	3.57 (0.96)	16	2.0	8.0	3.76 (1.54)
Quantitative Concepts (pre)	23	2.3	5.5	3.71 (0.85)	7	2.7	4.7	3.71 (0.68)	16	2.3	5.5	3.71 (0.93)
Attitude (pre)	23	3.0	16.0	8.87 (2.91)	7	3.0	8.0	5.71 (1.60)	16	8.0	16.0	10.25 (2.18)
Calculations (post)	21	3.0	6.0	4.30 (0.82)	6	4.0	6.0	4.43 (0.71)	15	3.0	6.0	4.25 (0.87)
Applications (post)	21	2.0	10.0	4.56 (1.71)	6	4.0	5.0	4.58 (0.49)	15	2.0	10.0	4.55 (2.03)
Quantitative Concepts (post)	21	2.0	6.0	4.47 (0.97)	6	3.0	6.0	4.63 (0.83)	15	2.0	6.0	4.40 (1.05)
Attitude (post)	21	5.0	16.0	9.05 (2.44)	6	5.0	9.0	6.83 (1.47)	15	6.0	16.0	9.93 (2.19)
Control Grade 5												
Age	19	9.11	10.11	9.85 (0.34)	6	9.11	10.09	9.88 (0.38)	13	9.11	10.4	9.84 (0.42)
Calculations (pre)	19	3.0	5.6	4.34 (0.83)	6	3.0	4.5	3.67 (0.52)	13	3.8	5.6	4.65 (0.78)
Applications (pre)	19	2.6	6.8	5.16 (1.22)	6	2.6	5.8	4.57 (1.30)	13	3.0	6.8	5.44 (1.12)
Quantitative Concepts (pre)	19	3.0	4.7	4.05 (0.49)	6	3.0	4.3	3.78 (0.58)	13	3.7	4.7	4.17 (0.40)
Attitude (pre)	19	7.0	15.0	10.42 (2.50)	6	7.0	9.0	8.00 (0.89)	13	8.0	15.0	11.54 (2.18)
Calculations (post)	19	1.0	6.0	4.92 (1.21)	6	5.0	5.0	4.75 (0.27)	13	1.0	6.0	5.00 (1.47)
Applications (post)	19	3.0	10.0	6.08 (1.61)	6	3.0	8.0	5.75 (1.80)	13	4.0	10.0	6.23 (1.57)
Quantitative Concepts (post)	19	3.0	8.0	5.28 (1.12)	6	4.0	6.0	4.87 (0.63)	13	3.0	8.0	5.47 (1.26)
Attitude (post)	19	6.0	16.0	10.89 (2.75)	6	6.0	10.0	8.50 (1.52)	13	9.0	16.0	12.00 (2.48)

Results

Quantitative Data

Table 1 presents some descriptive statistics on the pre- and post-test results (z-scores or scaled scores) using the aforementioned subscales from the WJ and the TOMA. Data for the entire classes are presented, as well as for the at-risk and remaining non-at-risk groups.

Within group. As one would expect, there should be within-group growth over the course of a school year. Both the experimental and the control grade 2 non at-risk groups experienced significant changes from pre-to post-test on the three skill subtests of the WJ (*Calculations*, *Applied Problems*, *Quantitative Concepts*) (Table 2). The non at-risk experimental group also made a notable change in attitudes, nearing statistical significance ($Z = -0.590$, $p = .056$). However, only the experimental at-risk group demonstrated significant changes in *Applied Problems* ($Z = -2.380$, $p = .018$) and attitudes for math (TOMA) ($Z = -2.210$, $p = .027$). The control at-risk group made no statistically significant improvements in any area.

There were slightly different patterns of changes within group at the grade 5 level. The experimental non at-risk group made significant improvements in two of the three skill areas (*Applied Problems* and *Quantitative Concepts*), but unlike the grade 2 experimental class, this group did not have a significant change in attitudes towards math (TOMA) (Z = .-0.450, $p = .653$). The only significant improvement for the at-risk experimental group was in the *Quantitative Concepts* skill area ($Z = -1.990$, $p = .046$). Similarly, the control non at-risk group also made significant improvements in two of the three skill areas (WJ), and did not improve significantly in attitudes ($Z = -0.540$, $p = .590$). The at-risk control group made significant improvements in all three skill areas (*Calculations*, *Applied Problems*, *Quantitative Concepts*), but not in attitudes ($Z = -0.740$, $p = .461$).

Between group. Between group comparisons were done between whole class control and experimental groups, and also between the at-risk and non at-risk sub-groups which were created for each class.

Class to class. There were no statistically significant differences in gain scores on any of the measures when comparing experimental to control grade 2 groups (Table 3). However, there were significant differences between the gain scores for the grade 5 classes on the *Calculations* sub-test ($U = 116.500$, $Z = -2.071$, $p = .038$) and on *Quantitative Concepts* ($U = 113.000$, $Z = -2.355$, $p = .019$). Analysis of the raw data (Table 1) verifies that it was the grade 5 control group that made more significant gains than the experimental group. We used a corrected effect size measure as outlined by Masendorf (1997, p. 73) to quantify the differences between the two treatment conditions (experimental group [eg] vs. control group [cg]):

This formula accounts for any differences between groups that might have existed before the treatment was implemented.

$$d_{corrected} = \frac{M_{eg\,(post)} - M_{cg(post)}}{SD_{cg(post)}} - \frac{M_{eg(pre)} - M_{cg(pre)}}{SD_{cg(pre)}}$$

Table 2. ***Wilcoxon Signed Ranks Test Within Group - Pre-post Test Differences***

		Calculations	Applied Problems	Quantitative Concepts	Attitude
Grade 2 Experimental					
Non At-Risk	*Z*	-2.320	-2.940	-3.060	-0.590
	Sig. (2-tailed)	.021*	.003**	.002**	.056
At-Risk	*Z*	-2.370	-2.380	-1.580	-2.210
	Sig. (2-tailed)	.018*	.018*	.114	.027*
Control					
Non At-Risk	*Z*	-2.830	-0.306	-2.840	-0.300
	Sig. (2-tailed)	.005**	.002**	.005**	.763
At-Risk	*Z*	-1.600	-1.830	-1.840	-1.890
	Sig. (2-tailed)	.109	.068	.066	.059
d_{corr}					
Non At-Risk		-0.26	-0.60	-1.37	0.35
At-Risk		-0.23	0.28	-1.59	1.86
Grade 5 Experimental					
Non At-Risk	*Z*	-1.230	-2.200	-3.240	-0.450
	Sig. (2-tailed)	.219	.028*	.001***	.653
At-Risk	*Z*	-1.260	-1.790	-1.990	-0.680
	Sig. (2-tailed)	.207	.074	.046*	.496
Control					
Non At-Risk	*Z*	-1.970	-1.540	-2.750	-0.540
	Sig. (2-tailed)	.049*	.123	.006**	.590
At-Risk	*Z*	-2.230	-2.210	-2.210	-0.740
	Sig. (2-tailed)	.026*	.027*	.027*	.461
d_{corr}					
Non At-Risk		0.18	0.71	1.73	-0.24
At-Risk		-1.26	0.12	-0.26	0.47

Note. All *Z* scores based on negative ranks.
* p<.05, ** p<.01, *** p<.001

Table 3. ***Mann-Whitney Test Between Groups – Gain in Z-Scores***

	Calculations	Applied Problems	Quantitative Concepts	Attitude
Grade 2				
Mann-Whitney *U*	125.500	110.000	132.000	109.000
Z	-0.881	-1.394	-0.665	-0.948
Sig. (2-tailed)	.378	.163	.506	.343
d_{corr}	-0.12	-0.36	-0.38	0.50
Grade 5				
Mann-Whitney *U*	116.500	197.500	113.000	185.000
Z	-2.071	-0.054	-2.355	-0.400
Sig. (2-tailed)	.038*	.957	.019*	.689
d_{corr}	-0.09	0.25	-0.03	-0.05

Note. * p<.05, ** p<.01, *** p<.001

Non at-risk to at-risk group. Although the grade 2 at-risk experimental students made significant within group gains, they were not statistically significant when compared to their non at-risk peers. (Table 4). Similarly, in the control grade 2 classroom, at-risk students made no better gains than their non at-risk counterparts on any of the measures, including attitudes towards math. This held true for the 5th graders, as well, where there were no significant differences in the gain scores of the at-risk versus non at-risk peers within their respective classrooms, with the exception of the control class on the *Calculations* sub-test. Reviewing the descriptive data reveals that it was the at-risk group who made the stronger gains (U = 13.500, p = .022).

Qualitative Data

The qualitative data appear to confirm some of the findings from the quantitative data analysis. Fiona, the teacher of the grade two experimental group, noted that in general, the children "showed a lot of interest and enthusiasm while practicing their skills", "felt proud of being the only students (at their school) learning this method", and "enjoyed using their fingers." In addition, Fiona saw "huge" changes in the attitudes of the lowest functioning students. All of the children were overt about their finger tapping at the post-testing, and two of the at-risk children routinely used *Chisanbop* during regular math class instruction. Fiona also noted that "some students are more accurate using *Chisanbop*", although the quantitative data does not support this perspective.

Table 4. ***Mann-Whitney Test Between Groups – Non At-Risk and At-Risk Gain Z-Scores***

	Calculations		Applied Problems		Quantitative Concepts		Attitude	
Grade 2 Experimental	Mean Rank	Sum of Rank	Mean Rank	Sum of Rank	Mean Rank	Sum of Rank	Mean Rank	Sum of Rank
Not At-Risk	10.35	134.50	8.46	110.00	10.27	133.50	8.38	109.00
At-Risk	9.25	55.50	13.33	80.00	9.42	56.50	12.40	62.00
Mann-Whitney *U*	34.500		19.000		35.500		18.000	
Sig. (2-tailed)	.692		.077		.757		.144	
Control								
Not at Risk	8.83	106.00	9.29	111.50	9.46	113.50	6.73	74.00
At-Risk	7.50	30.00	6.13	24.50	5.63	22.50	11.50	46.00
Mann-Whitney *U*	20.000		14.500		12.500		8.000	
Sig. (2-tailed)	.622		.248		.161		.064	
Grade 5 Experimental								
Not At-Risk	9.32	130.50	11.50	172.50	10.10	151.50	9.93	149.00
At-Risk	13.25	79.50	9.75	58.50	13.25	79.50	13.67	82.00
Mann-Whitney *U*	25.500		37.500		31.500		29.000	
Sig. (2-tailed)	.172		.557		.290		.204	
Control								
Not At-Risk	8.04	104.50	9.35	121.50	10.88	141.50	9.73	126.50
At-Risk	14.25	85.50	11.42	68.50	8.08	48.50	10.58	63.50
Mann-Whitney *U*	13.500		30.500		27.500		35.500	
Sig. (2-tailed)	.022*		.467		.323		.765	

Note. * $p<.05$, ** $p<.01$, *** $p<.001$

Martin, the teacher of the grade five experimental group, did not see a notable change in the skills or attitudes for the group as a whole, noting that there was "some resistance with the older kids" and many students were capable of successfully doing the calculations "in their head just as quickly" and, therefore, did not use *Chisanbop*. The quantitative data did, however, indicate a significant skill improvement in applied problems and quantitative concepts. What was noticeable were the types of strategies that the students employed while solving math problems. The lower functioning students used finger tapping covertly, keeping their hands close to their bodies (sometime under the table), as if to hide the use of this strategy. However, the finger tapping did not appear to be the *Chisanbop* method. Higher functioning students used drawing, tally marks, or solved the problems in their heads. Martin indicated that the students were overall more "entrenched" in the other strategies that they had been taught since beginning school in grade one, and were reluctant to use *Chisanbop*. This parallels the quantitative findings for the entire class which indicate that students' attitudes towards math did not change significantly.

Both teachers indicated that they experienced some difficulty incorporating *Chisanbop* into their curriculum. Students did not always seem excited to fall back on this approach (especially the 5th graders), and Fiona, as well as, Martin obviously applied alternative methods at times, even though they were supposed to stick with the finger counting technique.

Discussion

Main Findings

The purpose of the present study was to evaluate the effects of a finger calculation method (*Chisanbop*) on the number sense, basic fact, and place value skills, as well as on the attitudes towards math of 2nd and 5th graders. We expected the intervention to have positive impacts on these dependent variables, especially with 2nd graders, and particularly with children at-risk for mathematic failure, which was the case for all but *Quantitative Concepts*. Of all groups, across all grades, only the grade 2 at-risk experimental group had significant improvements in attitudes. Growth in skills and attitudes at the grade 5 level was inconsistent, within both at-risk and non at-risk groups. But contrary to what we expected, the 5th graders in the at-risk control group showed greater progress than the at-risk students in the experimental group regarding their ability to perform calculations and applied problems.

The *Chisanbop* method seemed to spark a noteworthy change in attitude in at-risk second graders. A calculation of a corrected effect size yielded a standardized mean difference of 1.86. Such a value can be considered very large (Ellis, 2010). The grade five experimental group did not make significant improvements in attitude, however, and this may be because younger children are less embarrassed or self-conscious about trying a finger calculation method. In addition, younger children may respond more positively because it appeals to their hands-on/physical learning style, or because the use of "fingers" is not discouraged, as it is in the intermediate grades.

The quantitative and qualitative data indicate that the *Chisanbop* finger calculation method was beneficial for the at-risk grade 2 children. The experimental at-risk grade 2 children made changes in attitudes, while the control at-risk students did not. It may be that these children began to have success with calculations and applied math problems, and this improved attitudes toward math.

There were gains in one skill area (*Quantitative Concepts*) for those children in the lowest 30% of the grade 5 experimental class, but no change in attitudes toward math. One explanation may be that attitudes at this level are harder to change. In addition, students may not have seen the connection between a new and useful method and eventual skill improvement.

Limitations

The lack of significant changes in the experimental group when compared to the control group regarding different aspects of math performance might at least be, in part, due to problems with the implementation of *Chisanbop*. Both Fiona and Martin struggled to incorporate this new methodology into their curriculum. Similarly, the students were somewhat reluctant to use their fingers to represent numbers or do basic calculations, and this was particularly true for the grade five students. While efforts were made to heighten fidelity of treatment, more careful monitoring of implementation is required. We have to suspect that the intervention was not always applied as intended. Implementing intensive remedial programs on a class-wide basis (particularly at the intermediate level) over the course of a whole school year entails serious problems. In our case, these challenges could have easily influenced the results.

Another potential threat to the internal validity of our study is the fact that we had to use existing classes as experimental and control groups. As mentioned above, the students receiving the *Chisanbop* intervention showed some considerable gains in their math skills. However, the gains in the control group students were also remarkable. If teachers know that the performance development in their classes serving as a control group will be monitored and compared to the progress in parallel classes receiving a special treatment, this will oftentimes motivate them to try especially hard when supporting their students to acquire certain skills or concepts. A more selected group of participants (possibly just students who are experiencing difficulty with basic math concepts) at the upper-grade levels is recommended.

In our experiment, we followed the common practice in the local school district and used attitudes towards math as the main decisive factor for determining whether a girl or a boy was at-risk for math failure. Even though a number of studies support such an approach (see above), it could be argued that actual performance data of the subjects on standardized math tests should have played a greater role in labeling them as being at-risk.

Other limitations concern the small sample size, and in the case of the grade five classes, the fact that the groups were not equivalent at the beginning of the intervention. A larger and randomized controlled experiment could have provided more valid results than the present study. The same would be true had we made provisions for collecting some follow-up data. Another limitation pertains to the set of statistical inferences that we considered simultaneously. The more dependant variables one compares, the more likely it becomes that the experimental and the control group will appear to differ on at least one attribute by random chance alone (Leon, 2004).

Lastly, the inherent subjectivity of the qualitative data collection and analysis needs to be acknowledged. We used the transcripts from the joint meetings with Fiona and Martin, the teacher journals, the teacher emails, and the summary of notes of informal teacher meetings as supplemental sources to help us to gain some insights on why the intervention did or did not work. However, in order to draw even more meaningful conclusions, we would have had to conduct the data collection and analysis more systematically, and with more rigor.

Practical Implications and Future Research

The connection between finger representation and numerical comprehension is now undisputed. Quite a number of theories and empirical findings suggest that an approach like *Chisanbop* holds the potential to help struggling learners acquire basic math concepts. However, current arithmetic instructional practices do not, yet, incorporate systematic finger counting and calculation strategies. Indeed, the focus of mathematical instruction in the past two decades has not been on finger representation. Our study is the first in many years that evaluated the effects of *Chisanbop*. But our experiment certainly has its flaws (see above). Consequently, further study in the use of a finger calculation methodology is warranted for remedial purposes, particularly at the elementary grade levels. In promoting such efforts in future experiments, the aforementioned limitations (no randomized groups, no follow-up data, multiple comparisons, …) need to be considered.

In addition, the differential effectiveness of *Chisanbop* has to be evaluated in greater depth. Our work yielded some indications that the intervention is especially useful for students struggling with basic math concepts. However, some more details are required. As more children are included in general education classrooms, it is important for teachers to have a wide array of research-based practices to address the expanding learning needs of today's classrooms. They have to be able to fall back on a variety of different approaches that help different kinds of students. As we elaborated on earlier, using fingers during a certain age while calculating is not an indication of a child experiencing problems in math, but part of her or his normal development. Helping a student to consolidate the concepts that she or he needs to learn during that particular phase in order to later progress to higher-order abilities is certainly a worthwhile endeavour. Even though our experiment did not yield impressive effects that document the benefits of *Chisanbop*, it is surely not appropriate to throw out the baby with the bath water. Too many reasons boost the notion that finger counting techniques possess the potential to provide a certain kind of support that other approaches cannot facilitate. Thus, the need for research-based instruction (and particularly for effective math interventions involving one's fingers) is apparent. This study gives rise to the hope that *Chisanbop* might be a helpful method for elementary school children who are at-risk for math failure through changing their outlook on calculating. In particular, with more positive attitudes towards mathematics, it may be possible to also increase math performance and long-term success with numerical comprehension.

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APPENDIX A

Excerpt from Chisanbop finger math: An information booklet (p. 1)

Right *and* left handed children use this counting system.

1. Begin by using right hand only. Have children trace around their right hand and number each finger as ***ONE*** and the thumb as ***FIVE***.

2. Pressing begins with "one by one counting" (use this term with children).

3. Ask, "Are **you** ready?" and point with pointer finger. Ask all children to point with right pointer finger. This is the finger they begin pressing with. Teacher demonstrates on blackboard where class can see.
   a) Press one. Clear.
   b) Press one and one more. Read. Clear.
   c) Press one and one more and one more. Read. Clear.
   d) Press one and one more and one more and one more. Read. Clear.

* **Be sure all the children are starting with pointer finger then middle, ring and baby.**

Practice until everyone is firm.