Does the Japanese abacus improve underachieving children's performance in mathematics?

Nisih Freeman
The Abacus Club

This study reports the results of a pilot mathematics intervention program carried out over a period of 10 weeks, looking at the benefits of using the Japanese abacus with a small group of underperforming Year 1 children in a UK school. It investigates the rate of progress of children who have participated in the abacus sessions against a control group. Standardised tests at pre- and post-intervention stages are used to examine a number of features of the children's performance, including computational skills, oral counting, identification of numbers, objects counting and language. The results show that children who participated in the abacus sessions have progressed at an average rate of 40% against the control group of 8%. The intervention group displayed a particularly strong improvement in their computational skills.

Keywords: Japanese abacus; place value; number concepts; early maths intervention

Introduction

Against an earlier view that pre-school children's mathematical knowledge was in essence 'blank slate' and they started learning when they entered formal education in a school setting, various researchers have found the contrary. There is a growing literature looking into children's early numerical competence ('Number Sense') and acquisitions (Baroody & Wilkins, 1999). The ability to estimate and compare magnitudes of groups of objects, the understanding of one-to-one correspondence, cardinality, number sequences, manipulation of numbers in a set through additions and subtractions (3 + 2 = 5; 3 = 5 - 2) has been shown to be an important indicator of children's later mathematical achievements (see, for example, Jordan, Kaplan, Ramineni, & Locuniak, 2009; Mazzocco & Thompson, 2005; Duncan et al., 2007). Duncan et al. concluded that children who were behind in their early number competence were very likely to lag behind over the course of their schooling years. The finding is further supported by Jordan et al. (2009) who found that early quantitative ability explained as much as 66% of the variability in third grade children's mathematics achievement. They indicated that the understanding of simple arithmetic is particularly important.

This pilot study explores the use of the Japanese abacus as a hands-on tool in developing children's early conceptual understanding of numbers. The abacus is used as a counting tool which does not only aim at promoting children's understanding of quantities, but also develops their understanding of place value concepts. Early understanding of these concepts is essential in enabling children to develop a good foundation when dealing with harder sums (see, for example, Moeller, Pixner, Zuber, Kaufmann, & Nuerk, 2011; Hiebert & Wearne, 1992; Ho & Cheng, 1997). Moeller et al. (2011) further found that immature early understanding of place value to be highly predictive of mathematical difficulties experienced in later school years.

While the concept of place value is very simple, it seems to baffle many children. For example, many of them misunderstand that the number 11 consists of a one and a one. Various studies have reported the difficulties in children grasping the concept (Gervasconi & Sullivan, 2007; Thompson, 2000; Fuson, 1990). Gervasconi & Sullivan, for example, found that only 10% and 27% of six and seven year old children respectively in Australia demonstrated an understanding of the concept.

The benefits of using the Japanese abacus

The Japanese abacus (Soroban) is a tactile tool which has been adopted as part of mathematics curriculum by many primary schools in Asia in addition to being taught outside the formal school settings as part of out-of-school activities. Recent research carried out by the University of Harvard investigated the benefits of abacus training over a period of three years on elementary school children in India (Barner et al., 2014). Researchers observed a significant improvement in the control group's mental arithmetic skills against the experimental group after a year of training and noted that the effects became more pronounced as the training continued into the third year. Similar results were also found by Amaiwa & Hatano (1989) and Irwing, Hamza, Khaleefa, & Lynn (2008). The latter further found that the soroban training resulted in higher IQ points of 7.11 against a control group on a sample of 3,185 children in Sudan.

Other researchers have also pointed to the benefits of abacus training on children's cognitive capacities. Bhaskaran, Sengottaiyan, Madhu, and Ranganathan (2006) evaluated the effects of sight, sound, and finger movement coordination on abacus users' short-term memory after periods of one and two years of training. They observed the improvement in visuo-spatial and verbal working memory in abacus users. This finding is further supported by Barner et al. (2014) but they did not see the visuo-spatial effect persist after the first year of training. They did, however, find that children who have inherently better visuo-spatial ability tend to benefit from abacus training. Shen (2006) found that the soroban facilitates basic mathematical concept understanding in children who are cognitively challenged. In addition, it was also found to boost confidence in children and increase their interest in maths as a result (Foong, 1998; Shwalb, Sugie, & Yang, 2005).

The study

This study was conducted at a primary school in the UK involving seven year 1 children. The age range of the sample was from 5 years and 9 months to 6 years and 6 months. The study was carried out over a period of 10 weeks from early May to the end of July 2014 where 2 half-hour sessions were delivered each week in a group. While there were 20 sessions scheduled, only 18 were delivered due to a school performance and a post-intervention assessment.

The experimental group consisted of the 3 lowest performing children in the year group. The control group consisted of 4 children who were performing at a slightly higher SATS level. Permission from parents was obtained prior to the study being carried out. The material was taken from extracts of the Puffin book series created for The Abacus Club. The topics covered are detailed in Table 1.

Many interactive activities were incorporated within the sessions including the use of lego bricks, number charts, and soroban bead flash-cards to ensure that children did not only learn from this process but also enjoyed it at the same time. Sandwell Early Numeracy Test Revised, SENT-R, (Arnold, Bowen, Tallents, & Walden, Undated) was administered individually at pre- and post-intervention stages at the end of April and the middle of July 2014 respectively. This test looks into five strands of numerical skills (identification of numbers, oral counting, language, value/computation, and object counting). It was chosen as the test is designed to measure the effectiveness of a short intervention program such as this. In addition, any raw scores obtained from the pre- and post-intervention tests can provide us with information on their individual SATS levels and allows comparisons to be made against a sample of over 1,500 children in the UK.

Sessions 1 to 5	Object counting (1 to 9), linking objects counting to beads counting as well as Arabic numbers.
Sessions 6 to 10	Counting in twos, mental additions up to 10, place value concepts (up to 14), counting using the abacus.
Sessions 11 to 15	Counting in tens, exploring numbers up to 100, number bonds 5, mental additions of tens and units up to 15, counting using the abacus.
Sessions 16 to 18	Mental additions of tens and units up to 20, number comparisons (greater than/less than), odd and even numbers.

Table 1: Breakdown of topics covered within the intervention sessions.

Discussion of results

The overall results revealed that children in the experimental group showed strong improvement in different strands of numerical skills.

	SATS levels				**Age Equivalent**			
	Pre-intervention		**Post-intervention**		**Pre-intervention**		**Post-intervention**	
Children	**School**	**SENT-R**	**School**	**SENT-R**	**Apr. Age (yy:mm)**	**Apr. AgeEq (yy:mm)**	**July Age (yy:mm)**	**July AgeEq (yy:mm)**
W	1C	1A	1B	2C	05:10	05:06	06:01	06:04
Z	1C	1A	1B	2C	05:09	05:06	05:11	06:02
Fa	1C	1B	1A	2B	06:00	05:06	06:03	06:11
J	1B	2B/A	1A+	2B	05:11	07:01	06:01	07:03
A	1B	2C/B	1A	2C/B	06:06	06:07	06:09	06:04
Fi	1B	2C	1A	2B	05:09	06:04	06:00	07:01
O	1B	2C	1A	2B	06:06	06:08	06:09	07:00

Table 2: SATS levels given by school and SENT-R. Age equivalent (AgeEq) table compares students' numerical understanding given their actual ages (Apr. Age and July Age) at the time of assessment against a sample of over 1,500 children. W, Z, Fa are part of the experimental group and J, A, Fi, and O are part of the control group.

On the SATS measure, the school-assessed levels differed from those assigned by the SENT-R at each of the pre- and post-intervention periods. For example, child W was given level 1C by the school, but assessed to be at 1A by the SENT-R at the pre-intervention stage. As the levels differed, I investigated the improvement achieved by each child under each assessment between two dates. The expected age-related SATS level achievement at the end of year 1 is 1A, where 1A is the highest sub-level and 1C is the lowest. From Table 2, both school and SENT-R agreed that the children in the experimental group all made progress ranging from 1 to 3 sub-levels. Fa, for example, made progress of 3 sub-levels under SENT-R. The control group's assessments under the two measures, on the other hand, were mixed. While the school placed all the children to have progressed by 1 sub-level, the SENT-R did not detect any improvement in the first two children (J and A).

Under the Age Equivalent (AgeEq) measure, the experimental group all performed below their average age prior to the intervention study (see Table 2, Pre-intervention). They demonstrated better numerical concept understanding than their peers after the intervention. Fa, for example, showed substantial progress from falling behind her peers by 6 months (Apr. Age of 6 years (06:00) against Apr. Age Equivalent of 5 years and 6 months (05:06)), to advancing by 8 months (July Age of 06:03 against July Age Equivalent of 06:11).

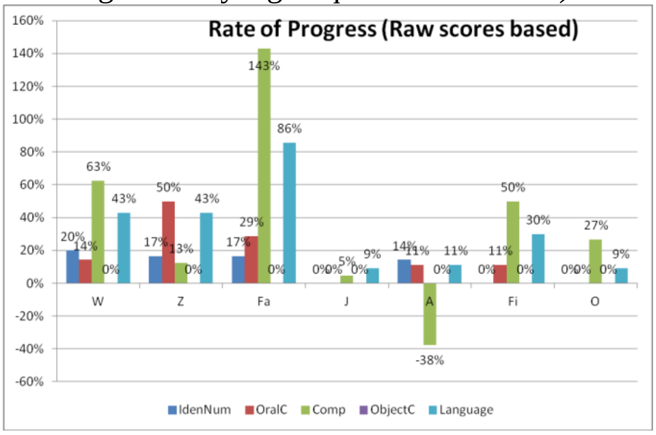

Figure 1: IdenNum, OralC, Comp, ObjectC, and Language refer to identification of numbers, oral counting, value/computation, object counting, and mathematical language respectively.

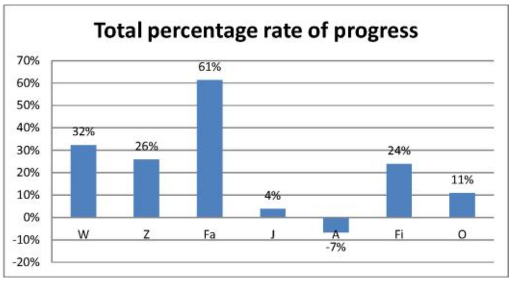

Figure 2: The total rate of progress is calculated by comparing the raw scores at post-intervention against pre-intervention.

These improvements can be further traced to their individual performance in the different strands of numerical skills investigated (Figure 1). All children in the experimental group showed progress in four out of five strands assessed. There is particularly a noticeable improvement in two out of three children's computational skills (63% and 143%). Both children did well on questions involving mental arithmetic for sums up to 20 and place value identification. The lower progress seen in child Z (13%) in this category could be due to him missing the last 3 sessions. This is further reflected in Figure 2 where Z has the lowest rate of progress of 26%. The child has, however, scored very well in oral counting and demonstrated much better understanding of mathematical language. No improvement was seen in object counting (ObjectC) as all children obtained full marks at the pre-intervention test.

Within the control group, it is interesting to note that J who performed very well in the April test, did not progress significantly before July. This could be due to the lack of challenge posed by the school during this period. Child A who performed at the average for her age in April, fell behind her peers in the July test. Fi was the only child in the group who showed a good improvement in numerical skills. This was due to the improvement shown in writing numbers correctly. Overall, Figure 2 revealed that the smallest progress achieved by Z in the experimental group (26%) still surpassed the highest rate of 24% obtained within the control group.

On the percentile ranking measure, it can be seen that both W and Z progressed well from the 40th to 53rd and 68th percentile respectively. Fa who was at the 24th percentile prior to the intervention, made excellent progress to rank in the 78th after the intervention. Within the control group, both J and A went down in the percentile ranking while Fi and O progressed from the 77th and 44th percentile to the 83th and 61st respectively.

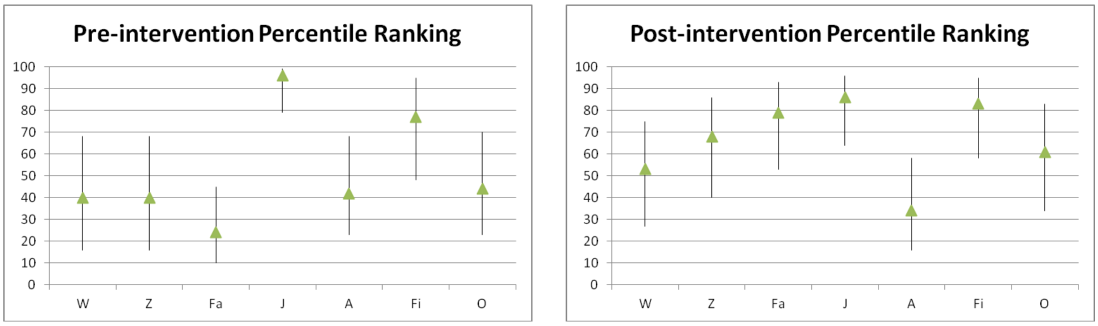

Figure 3: Pre- and post-intervention percentile ranking for each child. The green triangle refers to the percentile ranking for each child. The vertical line around the green triangle refers the 95% confidence bands.

Conclusion

In this pilot study, I examined the benefits of using the Japanese abacus as part of an intervention program on a small group of the lowest performing year 1 children in a UK primary school. The post-intervention test reveals that children in the intervention group showed good or excellent progress on all measures (SATS level, age equivalent, raw scores, and percentile ranking). It is particularly observed that two of the three children in the group performed very well in their computational skills. Overall, they demonstrated improving understanding and recognition of numbers, mathematical language and place value concepts. The lowest rate of progress obtained within the experimental group was still higher than the best performing child in the control group. A short parent survey revealed that the children greatly enjoyed the abacus sessions and have shown higher numerical confidence following the intervention.

Given the preliminary findings from this study, further research is required to investigate the extent to which the Japanese abacus can benefit a larger sample of underachieving children in the UK. The research can be extended in various ways. The period of the intervention can be extended to examine whether the effects persist and become more pronounced with time. One can also examine whether the superior progress seen within the experimental group is due to their underlying cognitive capacities. There is also an argument for re-assessing the performance of the children at different intervals after the intervention to see whether the progress achieved lasts. It will also be interesting if a comparison can be drawn between groups of children who have received different methods of intervention.

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