LEARNING ABACUS: WHAT COGNITIVE PROCESSES DO PUPILS USE?

Review by Foong Pui Yee

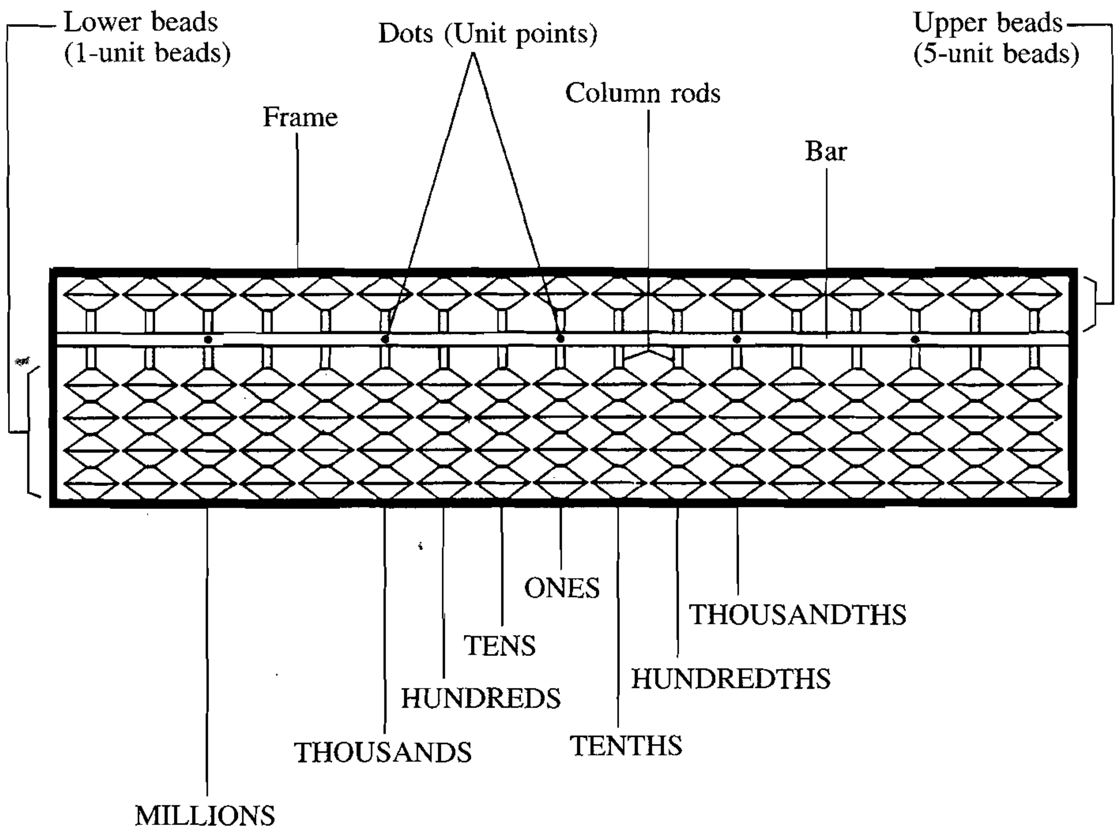


Figure 1: Structure of the Soroban (Cheong & Sin, 1996)

INTRODUCTION

The implementation of abacus instruction for all primary schools as a directive from the Ministry of Education in Singapore was initially met with surprise and some resistance from teachers who had no idea what it was and how it should be taught. Many were of the opinion that it was unnecessary to encumber children with an ancient device in this hi-tech age. The abacus was introduced into the Singapore primary school mathematics curriculum in 1995 as a learning aid to promote the development of mental calculation and to stimulate interest in the learning of mathematics. By the end of 1998 all Primary 2 and Primary 3 pupils will be trained in the use of abacus for addition and subtraction as an enrichment to the conventional methods of computation that they have been exposed to since primary one. This article gives a background to abacus instruction in local schools and research findings on its effect in mathematics learning.

THE ABACUS AND ABACUS INSTRUCTION

The origins of the abacus are not well known. Invented about five thousand years ago it was used universally for centuries in

Asia, the Middle East, Russia and Europe. The abacus was modified to its form of seven beads 1800 years ago in China. It eventually found its way to Japan during the 16th century where it was adapted and modified to five beads for increased speed and accuracy of calculations. The Japanese version of the abacus known as ***soroban*** uses a five bead structure with one row of beads above the dividing bar and four rows below it as shown in Figure 1. In the old days before the emergence of cash-registers and cheap pocket calculators, the abacus was an indispensable tool for day-to-day commercial activities in many parts of Asia, especially in China, Japan, Taiwan and in Singapore among the Chinese merchants.

Although the importance of the abacus has diminished in this hi-tech age, the soroban version still survives in Japan and Taiwan in two forms: as an instructional tool in general education and as a special tool for competition on speed and accuracy in mental calculation. Basic abacus operations are taught to all Japanese children at grades 3 and 4 for addition and subtraction, as well as how to represent a number on an abacus (Hatano, 1997). In Taiwan, children are first introduced to the abacus as part of their grade 4 school mathematics curriculum. Children in both countries who wish to become experts undertake more intensive training by enrolling in after-school programmes. Many are motivated by an elaborate qualification system where participants are ranked through frequent examinations with the ultimate aim of achieving grand expert status as national champions. The abacus as a tool in elementary school education and as a national recreational competition in these two countries, has a long tradition mainly because it is considered as a valuable cultural property. Many parents believe that extra abacus instruction out of schools will foster diligence and self-discipline, which are considered important Asian values. They also believe that abacus dexterity will enhance calculation and estimation ability. In Japan many high schools and some junior highs have abacus clubs where players practise at least a few hours everyday to compete in matches and tournaments.

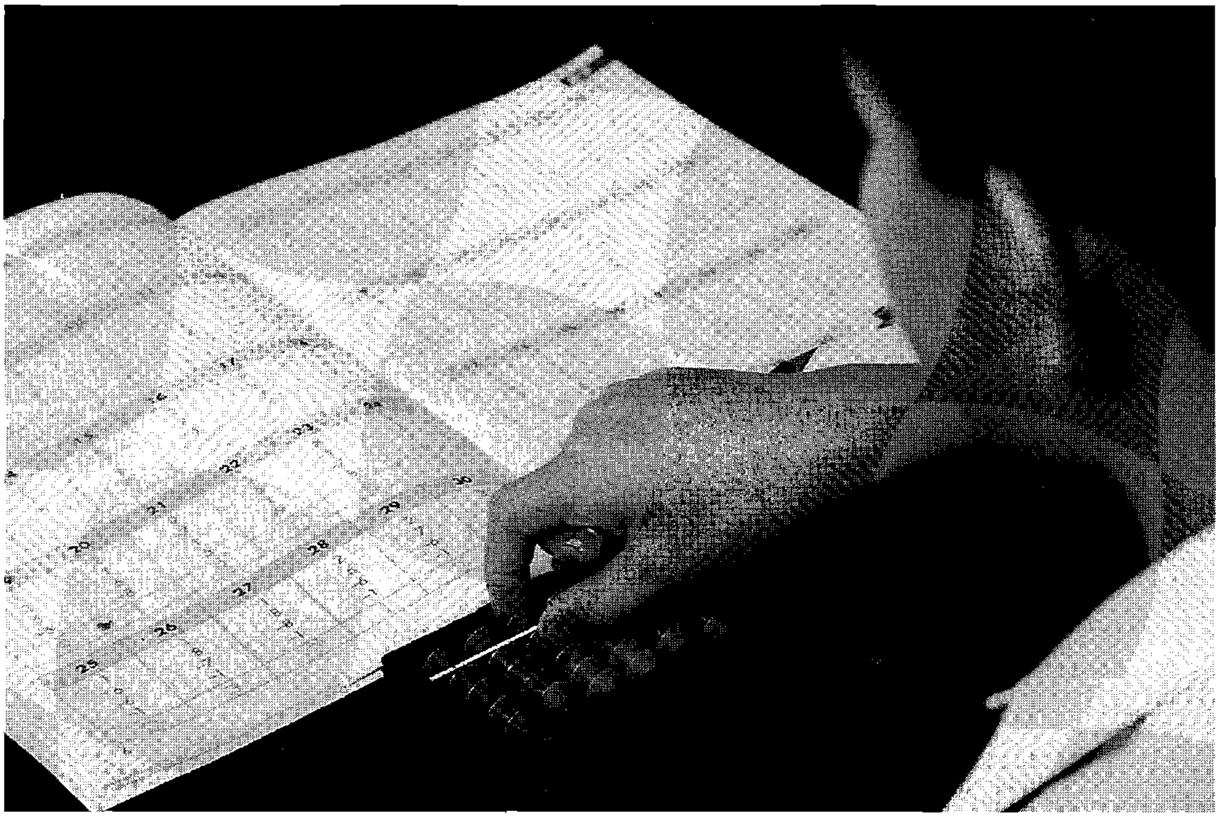
THE SINGAPORE EXPERIENCE

Abacus instruction in Singapore schools only began in 1995 based on a pilot study, involving 1113 Primary 3 pupils from 7 experimental schools and 7 control schools. The objectives of the study were:

- to measure the effectiveness of abacus training on mental calculation and understanding of place value concepts;

- to assess possible affective outcomes related to mathematics such as pupil interest, confidence and perception of ability.

Findings of the study (CDIS, Nov 97) were positive. Pupils in the experimental schools showed significant improvement in mathematical achievement tests. All pupils in the study sat for a pre-test and a post-test on a mathematics achievement instrument that contained questions on mental calculation and place value concepts.



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Moving beads on the abacus.

The results of this pilot study can be supported by another study in Japan by Amaiwa and Hatano (1989) as reported in Hatano (1997). Fifty-three 3rd-graders who had been learning abacus operation, were compared to 57 classmates who did not attend abacus lessons. They were assessed on two speed tests of basic calculation, and paper-and-pencil tests of multi-digit addition, subtraction, open sentence problems (e.g. __ plus 8 is equal to 41, ___ - 7 = 27), word problems and comprehension of the exchange principle between columns. The results showed that the abacus learners were much faster than the non-learners in basic calculations and on finding a complementary number to ten. They were also much better in performance on multi-digit subtraction problems, open-sentence problems and writing an expression for word problems than those who had no abacus training.

In the Singapore pilot study, a questionnaire measuring pupils' attitudes towards mathematics was administered before and after the experiment. It showed that the experimental group reported higher levels of interest and confidence in mathematics than their peers in the control schools. These positive results provided the incentive for the introduction of abacus skills in the syllabus. It was introduced to Primary 3 pupils in phases starting with 15 schools in 1995, and another 35 schools in 1996 and all schools in 1998. The Curriculum Planning Division of the Ministry of Education developed an 11-hour instructional programme with workbooks, guides and teaching aids for teachers and pupils. Five basic skills for manipulating the beads for addition and subtraction had to be taught to pupils, following the recommendations in the Teacher's Manual produced by Cheong and Sin (1996).

COGNITIVE PROCESSES USED IN ABACUS LEARNING

Abacus learning as a topic in the syllabus of elementary school mathematics might be seen by many in western countries as irrelevant and limited in instructional value if it is judged by the outcome of proficiency in computational skills at the expense of conceptual understanding. In mastering the abacus for mental calculation, rules and rote memory are important components that are often viewed as inferior in the age of electronic calculators and computers. Mathematics educators were forced to rethink the role of traditional paper-pencil algorithm for arithmetic and suggested a shift to conceptual understanding and problem-solving strategies if students were to use the calculators efficiently. However, criticism arose about the possible over-reliance on calculators. It was feared that children in their early learning of numbers and operations might not develop an adequate understanding of relationships between numbers. There has therefore been a move back to basic skills. Computation and mental computation are basic skills used across a wide variety of cultures. Practice for proficiency in skills has its place in mathematics education, although too much emphasis may be detrimental to conceptual learning. Most would agree that computation ability achieved through meaningful learning is instrumental to problem solving ability.

Studies by Hatano, (1997) and Stigler, (1984) have shown that abacus learners tend to do well in elementary school and this "success" may give them confidence in their mathematics ability. What cognitive processes are involved in the learning of abacus operations for arithmetic computations? Studies on expertise in abacus operations need to be seen from two perspectives.

1. The abacus experts who perform mental calculation by moving "beads" on the "mental abacus" who can find product of two 5-digit numbers in under 10 seconds. Their aim is to improve their skills for competition and the effects of practice on mathematical thinking are irrelevant for them.

2. The elementary school children learning abacus in the context of arithmetic. It is in the second category that researchers and educators are interested in finding the significance of practice on the abacus for the development of mathematical concepts.

In abacus lessons, children are taught the theory of abacus operation in terms of bead and finger movements. There is a large cognitive component in what would be viewed as primarily as a motor skill where specific fingering movements are stressed in manipulating the beads (see manual by Cheong and Sin, 1996). Calculations with an abacus are at an intermediate level of abstraction between calculation with Dienes base-ten blocks on the one hand and the written calculations on the other. Unlike the Dienes blocks, the abacus beads are all of the same size and a unit bead may represent one, ten or hundred depending on its position. Hence learning how to operate an abacus may help children acquire the notion of place-value. Children must first acquire an understanding of the operations such as addition and subtraction, and facility in knowing the complementary numbers in bonds of 5 and 10 before they can use the abacus for calculation. The abacus acts as an external memory and computational device. It registers a number as a configuration of beads and one can produce the answer to a given operation by manipulating the beads. When using the abacus to add or subtract numbers, children may have to subtract while adding or add while subtracting. Therefore, in learning to use the abacus for addition and subtraction, both these operations are taught at the same time.

The type of conscious cognitive processing that goes on in an individual learner will depend upon the philosophy of the teacher. Some teachers encourage beginners to "reason out" the correct move based on their understanding of place-values and number bonds of 5 and 10 when they are uncertain of how to proceed, without strict fingering movements. Here the role of the abacus is a hands-on manipulative which engages children's thinking while they learn the meaning of the mathematical ideas of adding and subtracting multi-digit numbers with and without carrying or "borrowing". Other instructors of the abacus would want children to achieve "mental abacus" calculation and insist on strict fingering movement and bead movements based on the rules taught and expect children to commit them to memory. This is usually the approach adopted in the intensive abacus programmes for children who want to be expert operators. However, within the time-frame of eleven hours allocated in the school mathematics curriculum for abacus learning in Singapore, it is not possible for children to achieve "mental abacus" calculation ability that will require many hours of practice. Nevertheless there is a growing trend similar to situations in Japan and Taiwan where Singaporean parents are sending their children for extra abacus training after school hours (Straits Times, June 14, 1996).

CONCLUSION

In the process of implementing abacus instruction in Singapore, training courses have been conducted to equip primary school teachers with the necessary abacus skills and appropriate teaching strategies. Schools which have been implementing the abacus instructional programme for the first year have been monitored closely through school visits by the mathematics unit officers. Cheng (1998) reports that the teachers' evaluation of the workshops showed they have enjoyed and benefited from the training. The teachers noted that the programme has benefited pupils in strengthening their number bonds, instilling self-discipline and building up their confidence in mathematics.

IMPLICATIONS

In order to provide useful information for gauging the success of the programme after it has been fully implemented further research is necessary in local schools to :

1. Gain valuable feedback from teachers on the **problems of implementing** abacus instruction in schools.
2. Investigate what **difference** abacus learning makes to pupils learning arithmetic and how it enhances their mental computation skills.
3. Study the **philosophy and concerns of teachers** towards teaching abacus to mixed-ability classes.

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