Effect of Abacus Training on Numerical Ability of Students with Hearing Loss

Atul Kaluram Jadhav[1*], Varsha Shrikant Gathoo[1]

1. Department of Education, Ali Yavar Jung National Institute of Speech and Hearing Disabilities, Mumbai, India

ABSTRACT

Purpose: *The study focussed on the effect of Abacus training on numerical ability (comprising of counting and mathematical operations) of children with hearing loss.*

Method: *90 students with hearing loss were sampled from 6 special schools in Mumbai, India. A quasi- experimental study was employed using two group pre-test and post-test design. Data were collected using the Numerical Ability Test (NAT) as an instrument. Six null hypotheses based on the objectives were formulated and tested at 0.05 level of significance using t-Test - Assuming Equal Variances.*

Results: *The findings revealed that the experimental group which was instructed through Abacus showed higher proficiency in numerical ability as compared to the control group instructed through the conventional method. Gender as a variable seems to influence the mean achievement of numerical ability of students with hearing loss. While girls and boys did not differ in simple tasks such as counting, boys were found to be better in mathematical operations and overall numerical ability.*

Conclusions*: The Abacus teaching method results in higher mathematical achievements among students with hearing loss. Gender also plays an important role in mathematical learning, as evidenced by boys demonstrating more numerical ability than girls in the study sample.*

Key words: *Abacus, numerical ability, counting ability, mathematical operations, students with hearing loss*

* **Corresponding Author:** Atul Kaluram Jadhav, Department of Education, Ali Yavar Jung National Institute of Speech and Hearing Disabilities, K C Marg Bandra Reclamation, Bandra (W), Mumbai, Maharashtra 400050, India. Email: atulrajejadhav@gmail.com

Vol. 29, No.2, 2018; doi 10.5463/DCID.v29i2.683

INTRODUCTION

Mathematics has an enormous applicability and is an essential language and framework for all sciences (Puebla, 2015). It lays a robust foundation not only for school subjects, but also for undertaking daily-life skills. Mastery over numeracy or numerical ability in children is fundamental to achieving mathematical literacy, as 'what spelling is to writing', 'numbers is to maths'. Teachers of the deaf have always been striving hard to develop numeracy for these children as they lag behind their hearing peers both in numerical ability and mathematical skills (Traxler, 2000). One reason for this is because deafness restricts acquisition of language, and language is important for allowing access to mathematical information. Zarfaty et al (2004), Pagliaro and Kritzer (2012), and Edwards et al (2013) also reiterate that historically children who are deaf and hard-of-hearing scored less in mathematics and other academic subjects as compared to hearing peers in the same age group. Studies from both deaf and hearing populations typically show a strong association between language and mathematical abilities (e.g., Kelly & Mousley, 2001; Hyde et al, 2003), with some researchers arguing that language is the key barrier to success, particularly in mathematics word problems (Marschark & Hauser, 2008).

Research has also shown that the process of cognitive development required for developing numerical ability and later mathematical skills seems to be closely connected with the development of verbal language. Estimation skills, a strong facilitator of mathematical learning, is found to be lacking in individuals with hearing loss. These skills have been characterised as part of number sense. Kritzer (2008) argued that because of their hearing loss and frequently impoverished language environments, some deaf children lack access to incidental learning opportunities that limit their exposure to early developing numerical concepts. This has been supported by Gregory (cited in Bull et al, 2011). As a result, they often lack the building blocks required for formal mathematics encountered during the later school years (Bull et al, 2011).

Mathematical Instructions for Children with Hearing Loss

Children with hearing loss learn mathematics at a delayed pace as compared to their hearing peers (Wood et al, 1983; Traxler, 2000). Various aspects to this are cited in the reviewed literature.

Many years ago Fridriksson and Stewart (1988) had suggested reasons for maths instructions receiving little attention in Teacher education programmes for deaf students. They observed that in the first place, training programmes to develop teachers for the deaf tend to emphasise speech and language skills, and the trainees are not provided with an adequate foundation in mathematics teaching. Secondly, mathematics in the classroom is often only pencil-and-paper learning, with little hands-on experimentation or computer use. Thirdly, mathematics is not seen as important, and progress in mathematical understanding is not stressed.

Along similar lines, Pagliaro (1998) also pointed out that if there is to be any hope of improving the mathematical performance of deaf and hard of hearing students, the mathematics competency of their teachers must be improved. The study highlighted that improvements in the mathematics preparation of teachers has direct relation to better instruction. This in turn would affect student learning and increase achievement. It has been further stressed that the society and economy of the 21st century will depend on mathematics-competent workers. Hence, the teacher competency has to be improved in order to prepare children with hearing loss to be effective persons of tomorrow. Towards this end the pedagogical practices in maths need attention.

According to Louie et al (2008), multiple approaches to teaching math concepts are needed, to help students with disabilities reach a deeper understanding of the subject. According to Pau (1995) and Nunes and Moreno (2002) evidence shows that principles and elements of Balanced Mathematics Instructions (BMI) are beneficial to students with hearing loss. This has been supported by Stewart and Kluwin (2001) and Pagliaro (cited in Tanridiler et al, 2015). BMI is remarkable as it consists of strong features of both direct instruction and constructivism. BMI defends the balance in determining whether there is a need for direct instruction or an indirect support depending on the preliminary knowledge of a student. It adopts the principles stated in the Primary Education Mathematics Teaching Programme (1998), which are as follows:

(1) Teaching should start with concrete experiences.

(2) Meaningful learning should be targeted.

(3) Students should communicate with their mathematics teaching.

(4) Association should be given importance.

(5) Student motivation should be considered.

(6) Technology should be used effectively.

(7) Cooperation-based learning should be given importance.

(8) Lessons should be organised by appropriate teaching stages.

The National Council of Teachers of Mathematics, Inc. (2004), lays emphasis on adaptation of instructional strategies for math teaching. It suggests that to make learning mathematics more accessible and rewarding for students with special needs, the students require instructional modifications and accommodations along with use of appropriate learning materials.

Role of Manipulative Material for Learning Mathematics

Mathematic learning is all about doing and practicing through use of objects generally referred to as manipulatives. Cope (2015) defines Physical Manipulative as an object which is designed for free manual movement for developing motor skills or understanding abstractions. Manipulatives are generally three-dimensional and range from simple everyday items, such as buttons, paper clips, toothpicks, etc., to more complex and discipline-specific items, such as calculators, two-colour counters, algebra tiles, and pantomimes (Bellonio, cited in Cope, 2015) and Abacus slates.

The history of the use of manipulatives for teaching mathematics is at least 200 years old and it has been stressed by Friedrich Froebel (1782 -1852), Maria Montessori (1870-1952), Jean Piaget (1896-1980), Zoltan Dienes (1916-2014) and Jerome Bruner (1915-2016) (Moore, 2014). Each of them has emphasised the use of experience through concrete tools for development of understanding. The National Council of Supervisors of Mathematics - NCSM (2013), in its position paper, suggests that for developing students' mathematical proficiency, leaders and teachers must systematically integrate the use of concrete and virtual manipulatives into classroom instruction at all grade levels. Manipulatives usually have moving parts that learners use to illustrate the math process concept. While providing guidelines for the use of manipulatives, Cope (2015) suggests that learners need explicit instructions on how to use manipulatives and each learner should individually get the opportunity to explore and investigate problems using manipulatives.

Abacus - a Manipulative Tool for Mathematics

Abacus is a classic tool consisting of a simple wooden frame with beads, making it portable and flexible in usage. It is used worldwide for teaching basic arithmetic in elementary classrooms. Abacus is useful because it helps to develop speed and accuracy of calculations (Stigler et al, 1986). It can be used to provide a sound basis for mathematical calculations like addition, subtraction, multiplication, and division. It can also be used to carry out calculations involving fractions and decimals, as well as an aid in completing arithmetic operations included in higher level mathematics (Research and Development Institute, Inc., 2006). According to Tanaka et al (2012), research has shown that skilled Abacus users are able to perform quick and accurate mental calculations using visual imaging of the manipulatives. Several studies have reported improvements in the numerical ability of subjects trained to use an Abacus. For instance, Hatano and Osawa (1983) reported that elementary school children trained to use an Abacus, performed significantly better on tests of calculation speed and accuracy compared with those who were not so trained. The numerical ability of Abacus users has inherently been better, as children tend to benefit from Abacus training. In addition, it was found to boost confidence in children and consequently increase their interest in maths (Foong, 1998; Shwalb et al, cited in Freeman, 2014).

Rationale for the Study

Several studies on the use of Abacus for children with visual and intellectual disabilities have been conducted (Beal & Shaw, 2009; Vita & Kataoka, 2014; Wanjiru et al, 2014; Matías-Guiu et al, 2016). Shen (2006) found that the use of Abacus facilitates basic mathematical concepts and understanding in children who are cognitively challenged. According to the Research and Development Institute, Inc. (2006) Abacus is one of the most effective calculation tools for blind children, when used in conjunction with other devices. However it is not sufficiently documented whether or not it is beneficial to children with hearing loss. In the Indian context, a survey documenting the use of Abacus, by Jadhav and Gathoo (2017), concluded that the special teachers had a lower level of functional and overall awareness about Abacus, as compared to the mainstream school teachers. One of the reasons cited was lack of documentary evidence on the benefits of Abacus. In the Indian state of Maharashtra where the present study has been conducted, many special schools for children with hearing loss opt for lower level maths or choose an optional subject instead of math. This is because many students with hearing loss find math to be a difficult subject (Nair & Ramaa, 2015). Since a baseline study undertaken for the present study found that majority of special schools only use the conventional method, an experimental study about the use of Abacus training was conceptualised.

Gender as a variable is also studied, as the outcomes of many studies reveal that boys tend to perform better than girls, especially in numerical problems, while girls perform better than boys in verbal tasks (Maitland, & Goldman, 1974; Arigbabu & Mji, 2004; Bassey et al, 2004; Kolawole, 2007). In the Indian context, gender as a variable has not been sufficiently documented with respect to mathematical achievement of children with disabilities and hearing loss in particular.

Objective

The main aim was to study the effect of Abacus training on numerical ability, comprising of counting and mathematical operations, in children with hearing loss. The gain in the numerical ability if any, in the experimental group, was also designed to be studied for gender as a variable. Based on the objectives, six null hypotheses were formulated and tested at 0.05 level of significance using t-Test - Assuming Equal Variances.

METHOD

Study Design

A quasi-experimental two group pre-test and post-test experimental design was employed, with the purpose of determining the effect of Abacus training on numerical ability of children with hearing loss.

Sampling

A list of the primary level special schools in Mumbai and sub-urban areas was obtained from the Social Welfare Department of the Government of Maharashtra. Of these, 12 special schools were shortlisted on the basis of having sufficient number of students in III and IV grades. From the 12 shortlisted schools, 6 special schools were then randomly selected. A sample of 90 students was finalised for the study. Treatment was randomly allocated to the students from special schools, thus dividing them into experimental and control groups. The distribution of the sample in experimental and control groups is shown in Table 1.

Table 1: Sample Distribution

Sample			
Groups	Gender		Total
	Male	Female	
Experimental	17	18	35
Control	25	30	55
Total	42	48	90

Research Instrument

The Numerical Ability Test (NAT) developed by Khire et al (2013) was used for data collection. The tool has four sub-tests and their respective reliability and validity is as shown in Table 2.

Table 2: Reliability and Validity of NAT

Sr. No.	Test No.	Reliability Coefficient	Validity Loading Obtained
1	Test 1	0.70	0.56
2	Test 2	0.83+	0.55
3	Test 3	0.77+	0.62
4	Test 4	0.81	0.32

NAT is designed to assess three aspects, namely, understanding of basic numerical concepts, simple numerical computations, and numerical reasoning. The first aspect refers to understanding of numbers and related concepts like odd, even, squares, etc. The second aspect refers to ability to add, subtract, multiply and divide quickly and accurately, and the third aspect refers to ability to use numbers in a logical and rational way. NAT had four sub-tests, namely (i) Cognition of Symbolic Systems (CSS), (ii) Convergent Production of Symbolic Units (NSU), (iii) Convergent Production of Symbolic Systems (NSS), and (iv) Evaluation of Symbolic Relations (ESR).

For the present study a theoretical model was developed, depicting the skills and abilities drawn from various sub-tests of NAT. It is diagrammatically represented below in Figure 1.

 Vol. 29, No.2, 2018; doi 10.5463/DCID.v29i2.683

Figure1: Baseline Theoretical Model of Numerical Ability

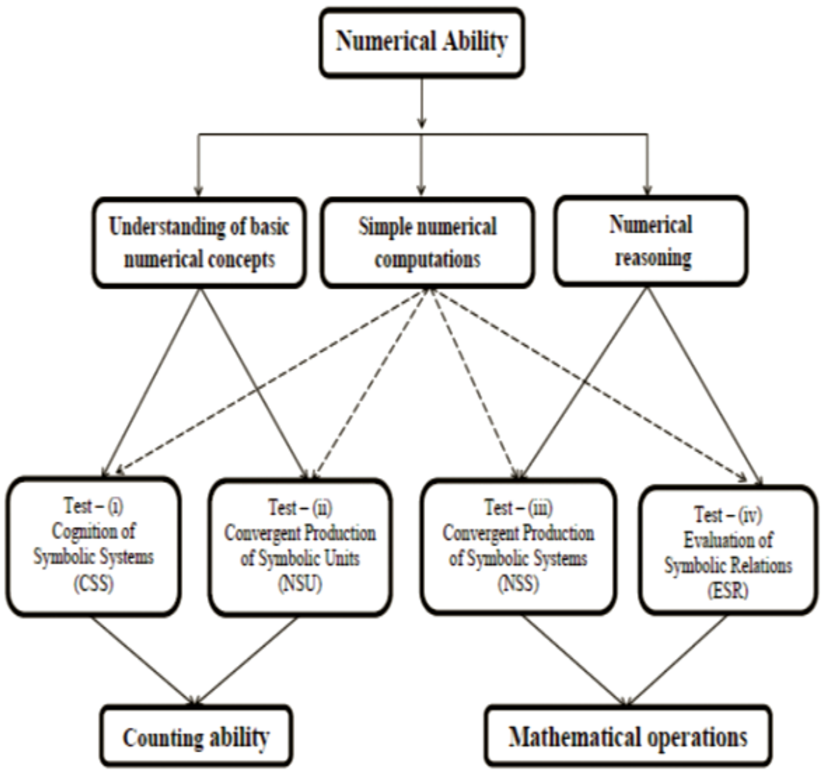

Table 3: Items on Numerical Ability Test

Test No.	Test Name	Categories clubbed for present research	No. of Items
1	CSS	Counting Ability items	10 + 9 = 19
2	NSU		
3	NSS	Mathematical Operations items	10 + 12 = 22
4	ESR		

Procedure

NAT was administered as a pre-test to both the Control group (CG) and Experimental group (EG) to measure the levels of numerical performance. The Experimental group received instructions through Abacus for a duration of 8 months and the Control group received instructions through the conventional method from the researcher. A time schedule was maintained and balanced so that both the groups were instructed in the morning as well as in the afternoon. NAT was administered as post-test to both the groups to compare their achievement in numerical ability.

RESULTS and DISCUSSION

Table 4: The Overall Gain in Numerical Ability of Experimental and Control Groups

Variable	Group	N	Mean Gain	Standard Deviation	't' value		Level of Significance at .05	Null Hypothesis
					Cal. value	Crit. value		
Counting ability	EG	35	2.06	1.08	5.88	1.99	Significant	Rejected
	CG	55	0.85	0.92				
Mathematical operations	EG	35	2.71	1.1	10.29	1.99	Significant	Rejected
	CG	55	0.62	0.82				
Numerical ability	EG	35	4.78	1.37	13.04	1.99	Significant	Rejected
	CG	55	1.45	1.03				

EG = Experimental Group and CG = Control Group

From the findings reported in Table 4, it can be concluded that the use of Abacus has resulted in significant positive differences between the achievements of numerical ability in the experimental group as compared to the control group. The experimental group has scored significantly higher in all the dependent variables. This could be attributed to the activity-based learning fostered by Abacus. Abacus is a slate with beads, and children learn visually through moving and manipulating the beads in rows and columns. The procedure of Abacus instructions has features of all the five approaches for developing numerical ability mentioned above. The Abacus training instructor first demonstrates the ways of counting and calculating to the students, and the students later practice on their individualised slates. The instructor also scaffolds wherever required. These are the features of the 'Demonstration approach' wherein students learn by observation and practice. Abacus instructions also incorporate the features of 'Inquiry-based approach' as it is student-centred. Children often work in pairs and groups undertake role reversals as instructors, so it is collaborative and based on the constructivist theories for development of higher-order reasoning.

Abacus is a 'Practice work approach' as the learners manipulate concrete objects, i.e., the beads, and/or perform activities to arrive at a conceptual understanding of phenomena, a situation, or a concept such as doing addition, subtraction or multiplication to quickly arrive at a solution. Since the instructor guides the students through the basics of counting and on to higher order abilities - such as place and face values, or how many more vs. how many less to reach a number - it follows the principles of 'Discovery approach' too. In the present study, Abacus training ranged from 'guided discovery' to 'free discovery' and the focus was on the procedure, i.e., how to learn. Children in the experimental group worked in small intense groups to solve a task such as depicting units, tens and hundreds, or the ascending vs. descending orders, so it covered the features of the 'Mathematics Laboratory Approach'.

Mathematics is generally considered a difficult and abstract subject where most of the students struggle to understand the basic concepts. Teaching and learning mathematics through an activity such as Abacus makes use of multiple senses (visual, auditory and kinaesthetic). Abacus training leads to forming mental imagery over time, as children imagine moving the beads and think logically, thus fostering mental maths. By performing mental math repeatedly, the ability to apply logic in other day-to-day life scenarios is built up as well. Hence, along with improving their counting ability, the experimental group might have fared better on the word problems. In contrast, when the conventional teaching method is employed, students are forced to learn mathematics through the lecture cum demonstration method, using only their auditory and/ or visual sense to solve problems on the board. Since no kinaesthetic sense is used, students may not be able to retain and apply their knowledge when it comes to word problems. Findings of the present study are in congruence with similar studies undertaken by Hatano and Osawa (1983) and Irwing et al (2008). Shen (2006) also found that ‘Soroban’ (a type of Abacus) facilitates understanding of basic mathematical concepts in children who are cognitively challenged.

Since the experimental group gained in the study, the next objective was to study whether the boys and the girls benefitted equally in their numerical ability by use of Abacus instructions.

Table 5: Overall Gain in Numerical Ability of Gender in the Experimental Group

Variable	Group	Gender	N	Mean Gain	Standard Deviation	't' value		Level of Significance at .05	Null Hypot-hesis
						Cal. value	Crit. value		
Counting ability	EG	Boys	17	2.35	1.22	1.61	2.03	Not Significant	Retained
		Girls	18	1.78	0.88				
Mathematical operations	EG	Boys	17	3.24	0.9	3.03	2.03	Significant	Rejected
		Girls	18	2.22	1.06				
Numerical ability	EG	Boys	17	5.59	1.12	4.16	2.03	Significant	Rejected
		Girls	18	4	1.14				

EG = Experimental Group

From the findings reported in Table 5, it is concluded that though girls and boys in the experimental group do not differ significantly in counting ability, boys perform better in mathematical operations and the overall numerical ability as compared to girls with hearing loss. This might be because the functions like simple counting are taught and reinforced both at home and at school at an early age, so that both boys and girls acquire those skills. Boys however outperformed the girls in other aspects of numerical abilities, i.e., mathematical operations. This is attributed to Indian culture whereby boys are assigned more outdoor tasks than girls and hence, over time, make faster word calculations. Research on the neural make up of boys and girls have proved that boys have faster and greater problem-solving ability. This result is supported by the study done by Casey et al (cited in Vani, 2014), wherein the researchers conclude that boys display greater confidence in their math skills, which is a strong predictor of math performance. The result of the present study is also in congruence with a study done by Bassey et al (2004) and work by other researchers such as Alio and Habor-Peters (2000), Raimi and Adeoye (2002), Ojo (2004), Odili and Maduabum (2007), Olowojaiye(cited in Akinsola & Odeyemi, 2014), and Onabanjo(cited in Adeyemi, & Adaramola, 2014), which concluded that boys performed better than girls in numerical and mathematical achievements. In the present research, the pre-existing superior abilities of the boys on word problems may have been enhanced due to the Abacus instructions and may have resulted in the overall gain for boys in the experimental group. Hence, gender may have had a significant effect on students' achievements in numerical ability.

CONCLUSION

- The use of Abacus results in higher achievements in numerical ability as compared to the conventional mathematics teaching method.
- Gender plays an important role in mathematical learning among students with hearing loss. While abilities of girls and boys do not differ in simple tasks such as counting, gender is found to favour boys in mathematical operations and overall numerical ability.

Recommendations

Based on the results of the current study, it is recommended that teachers need to use manipulatives like Abacus for teaching math to language-deficit children like those with hearing loss. Such aids are especially beneficial for kinaesthetic learners, inclusive of children with hearing loss.

Incidentally it was observed that students of the study's experimental group seemed to be highly motivated about the sessions. Their class teacher would receive enquiries regarding the next session of Abacus. Since the class teacher and school Principal requested that the Abacus instructions be continued, it is assumed that the children with hearing loss were well-disposed towards Abacus learning. Against this backdrop it is recommended that a unit in pedagogical practices, using manipulative materials such as Abacus, be included in the teacher training curriculum of special education. Alternately, the short-term training programmes conducted by the Rehabilitation Council of India (RCI) could list this as a topic for teachers' continuing education programmes.

ACKNOWLEDGEMENT

The authors wish to thank the special schools and the students who willingly participated in the study. Sincere gratitude is also expressed to the Director and the Department of Education of Ali Yavar Jang National Institute of Speech and Hearing Disabilities (D), for facilitating the study.

REFERENCES

Adeyemi OB, Adaramola MO (2014). Mathematics literacy as a foundation for technological development in Nigeria. Journal of Research & Method in Education; 4(5): 28-31. [Accessed on 16 Sep 2017]. Available from: http://www.iosrjournals.org/iosr-jrme/papers/Vol-4%20 Issue-5/Version-6/E04562831.pdf

Akinsola MK, Odeyemi EO (2014). Effects of mnemonic and prior knowledge instructional strategies on students' achievement in Mathematic. International Journal of Education and Research; 2(7): 675-688. [Accessed on 15 Sep 2017]. Available from: http://www.ijern.com/journal/July-2014/54.pdf.

Arigbabu AA, Mji A (2004). Brief report: is gender a factor in mathematics performance among Nigerian preservice teachers? Sex Roles; 51(11-12): 749-753. [Accessed on 10 Sep 2017]. Available from: https://link.springer.com/article/10.1007/s11199-004-0724-z https://doi.org/10.1007/s11199-004-0724-z

Bassey SW, Joshua MT, Asim AE (2004). Gender difference and mathematics achievement of rural and senior secondary school students in cross River state, Nigeria. Proceedings of epi STEMES; 56-60. [Accessed on 17 Sep 2017]. Available from: http://web.gnowledge.org/episteme3/pro_pdfs/09-bassy-joshua-asim.pdf

Beal CR, Shaw E (2009). An online math problem solving system for middle school students who are blind. MERLOT Journal of Online Learning and Teaching; 5(4): 630-638. [Accessed on 15 Sep 2017]. Available from: http://awvis.arizona.edu/sites/awvis/files/bealshaw2009.pdf

Bull R, Marschark M, Sapere P, Davidson WA, Murphy D, Nordmann E (2011). Numerical estimation in deaf and hearing adults. Learning and Individual Differences; 21(4): 453–457. [Accessed on 20 Sep 2017]. Available from: https://doi.org/10.1016/j.lindif.2011.02.001 https://doi.org/10.1016/j.lindif.2011.02.001

Cope L (2015). Math manipulatives: Making the abstract tangible. Delta Journal of Education; 5 (1): 10-19. [Accessed on 22 Sep 2017]. Available from: http://www.deltastate.edu/PDFFiles/DJE/spring-2015/dje_spring_2015_cope-final.pdf

Edwards A, Edwards L, Langdon D (2013). The mathematical abilities of children with cochlear implants. Child Neuropsychology; 19(2): 127-142. [Accessed on 25 Sep 2017]. Available from: http://www.deltastate.edu/PDFFiles/DJE/spring-2015/dje_spring_2015_cope-final.pdf https://doi.org/10.1080/09297049.2011.639958

Foong PY (1998). Learning abacus: What cognitive processes do pupils use? National Institute of Education (Singapore); 2: 24-29. [Accessed on 20 Sep 2017]. Available from: https://repository.nie.edu.sg/bitstream/10497/3796/1/REACT-1998-2-24.pdf

Freeman N (2014). Does the Japanese Abacus improve underachieving children's performance in mathematics? The British Society for Research into Learning Mathematics; 34(3): 13-18. [Accessed on 16 Sep 2017]. Available from: http://www.bsrlm.org.uk/wp-content/uploads/2016/02/BSRLM-IP-34-3-03.pdf

Fridriksson T, Stewart DA (1988). From the concrete to the abstract: Mathematics for deaf children. American Annals of the Deaf; 133(1): 51-55. [Accessed on 17 Sep 2017]. Available from: doi:10.1353/aad.2012.0631 https://doi.org/10.1353/aad.2012.0631

Hatano G, Osawa K (1983). Digit memory of grand experts in Abacus-derived mental calculation. Cognition; 15(1-3): 95-110. [Accessed on 18 Sep 2017]. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.650.4255&rep=rep1&type=pdf https://doi.org/10.1016/0010-0277(83)90035-5

Hyde M, Zevenbergen R, Power DJ (2003). Deaf and hard of hearing students' performance on arithmetic word problems. American Annals of the Deaf; 148(1): 56-64. [Accessed on 28 Sep 2017]. Available from: http://caidmathsig.wiki.educ.msu.edu/file/view/Deaf+Students+Performance+on+Arithmetic+Word+Problems.pdf https://doi.org/10.1353/aad.2003.0003

Irwing P, Hamza A, Khaleefa O, Lynn R (2008). Effects of Abacus training on the intelligence of Sudanese children. Personality and Individual Differences; 45(7): 694-696. [Accessed on 13 Sep 2017]. Available from: https://doi.org/10.1016/j.paid.2008.06.011 https://doi.org/10.1016/j.paid.2008.06.011

Jadhav AK, Gathoo VS (2017). Awareness about Abacus among teachers from special and regular schools. Educreator Research Journal, A Multidisciplinary International Quarterly Peer Reviewed; 4(3): 203-213.

Kelly RR, Mousley K (2001). Solving word problems: More than reading issues for deaf students. American Annals of the Deaf; 146(3): 253–264. [Accessed on 15 Sep 2017]. Available from: http://cimm.ucr.ac.cr/resoluciondeproblemas/PDFs/Ronald,K.%20%20Mousley,%20K..pdf https://doi.org/10.1353/aad.2012.0088

Khire U, Gadre S, Nirgudkar S, Gadre R, Watve S (2013). JPIP test of numerical ability. JnanaPrabodhini's Institute of Psychology. Pune.

Kolawole EB (2007).Gender issues and academic performance of senior secondary school students in mathematics computation tasks in Ekiti state, Nigeria. Pakistan Journal of Social Sciences; 4: 701-704. [Accessed on 22 Sep 2017]. Available from: http://docsdrive.com/pdfs/medwelljournals/pjssci/2007/701-704.pdf

Kritzer KL (2008). Family mediation of mathematically based concepts while engaged in a problem-solving activity with their young deaf children. Journal of Deaf Studies and Deaf Education; 13(4): 503-517. [Accessed on 24 Sep 2017]. Available from: https://doi.org/10.1093/deafed/enn007 https://doi.org/10.1093/deafed/enn007

Louie J, Brodesky A, Brett J, Yang L-M, Tan Y (2008). Math education practices for students with disabilities and other struggling learners: Case studies of six schools in two northeast and islands region states (Issues and answers report, rel 2008-no. 053).Washington, dc: u.s. department of education, institute of education sciences, national centre for education evaluation and regional assistance, regional educational laboratory northeast and islands. [Accessed on 16 Sep 2017]. Available from: https://ies.ed.gov/ncee/edlabs/regions/northeast/pdf/REL_2008053_sum.pdf

Maitland KA, Goldman JR (1974). Moral judgment as a function of peer group interaction. Journal of Personality and Social Psychology; 30(5): 699-704. [Accessed on 19 Sep 2017]. Available from: http://dx.doi.org/10.1037/h0037454 https://doi.org/10.1037/h0037454

Marschark M, Hauser P (2008). Deaf cognition: foundations and outcomes. New York: Oxford University Press, Inc. [Accessed on 20 Sep 2017]. Available from: http://hrcahvaz.ajums.ac.ir/_hrcahvaz/documents/book/23-%20Deaf%20Cognition.pdf https://doi.org/10.1093/acprof:oso/9780195368673.001.0001

Matías-Guiu JA, Pérez-Martínez DA, Matías-Guiu J (2016). A pilot study of a new method of cognitive stimulation using Abacus arithmetic in healthy and cognitively impaired elderly subjects. Neurología (English Edition); 31(5): 326-331. [Accessed on 23 Sep 2017]. Available from: https://www.sciencedirect.com/science/article/pii/S021348531500033X?via%3Dihub https://doi.org/10.1016/j.nrl.2015.02.002

Moore S (2014). Why teach mathematics with manipulatives? ETA hand2mind. [Accessed on 23 Sep 2017]. Available from: http://www.hand2mind.com/pdf/research/Why_Teach_Math_with_Manips.pdf

Nair PG, Ramaa S (2015). Analysis of errors made by children with hearing impairment. International Journal of Science and Research (IJSR); 4(3): 201-208. [Accessed on 17 Sep 2017]. Available from: https://www.ijsr.net/archive/v4i3/SUB151889.pdf

National Council of Supervisors of Mathematics (2013). Improving student achievement in mathematics by using manipulatives with classroom instruction. Denver, CO: Author.

National Council of Teachers of Mathematics - NCTM (2004). Teaching mathematics to special needs students. Teaching Children Mathematics. [Accessed on 17 Sep 2017]. Available from: http://www.cusdmathcoach.com/math_and_special_needs_students.pdf

National Council of Teachers of Mathematics – NCTM (2013). Mathematics in early childhood learning - NCTM position. [Accessed on 17 Sep 2017]. Available from: https://www.nctm.org/uploadedFiles/Standards_and_Positions/Position_Statements/Early%20Childhood%20Mathematics%20(2013).pdf

Nunes T, Moreno C (2002). An intervention programme for promoting deaf pupils achievement in mathematics. Journal of Deaf Studies and Deaf Education; 7(2): 120-133. [Accessed on 16 Sep 2017]. Available from: http://www.education.ox.ac.uk/ndcs/papers/nunesandmoreno2002.pdf https://doi.org/10.1093/deafed/7.2.120

Pagliaro CM (1998). Mathematics preparation and professional development of deaf education teachers. American Annals of the Deaf; 143(5): 373-379. [Accessed on 17 Sep 2017]. Available from: https://www.academia.edu/6031188/Mathematics_Preparation_and_Professional_Development_of_Deaf_Education_Teachers https://doi.org/10.1353/aad.2012.0137

Pagliaro CM, Kritzer KL (2012). The math gap: A description of the mathematics performance of preschool-aged deaf/hard-of-hearing children. Journal of Deaf Studies and Deaf Education; 18(2): 139-160. [Accessed on 14 Sep 2017]. Available from: https://doi.org/10.1093/deafed/ens070 https://doi.org/10.1093/deafed/ens070

Pau CS (1995). The deaf child and solving problems of arithmetic: The importance of comprehensive reading, American Annals of the Deaf; 140(3): 287-290. [Accessed on 16 Sep 2017]. Available from: https://muse.jhu.edu/article/385557/pdf https://doi.org/10.1353/aad.2012.0599

Puebla (2015). Mathematics: The music of the reason, music: Mathematics of the sense. [Accessed on 13 Sep 2017]. Available from: https://imsc.uni-graz.at/fripertinger/koll/Graz2015artic.pdf

Research and Development Institute, Inc. (2006). Calculation tools and aids - The Abacus. [Accessed on 14 Sep 2017]. Available from: http://www.tsbvi.edu/mathproject/ch5-sec3.asp

Shen H (2006). Teaching mental Abacus calculation to students with mental retardation. The Journal of the International Association of Special Education; 7(1): 56-66. [Accessed on 18 Sep 2017]. Available from: http://www.iase.org/JIASE%202006.pdf

Stewart DA, Kluwin TN (2001). Teaching deaf and hard of hearing students: Content, strategies, and curriculum. Boston, MA: Allyn & Bacon. [Accessed on 14 Sep 2017]. Available from: https://www.pearson.com/us/higher-education/program/Stewart-Teaching-Deaf-and-Hard-of-Hearing-Students-Content-Strategies-and-Curriculum/PGM62238.html

Stigler JW, Chalip L, Miller KF (1986). Consequences of skill: The case of Abacus training in Taiwan. American Journal of Education; 94(4): 447-479. [Accessed on 13 Sep 2017]. Available from: http://ucmasaustralia.com.au/wp-content/uploads/2014/06/stigler-1986.pdf https://doi.org/10.1086/443862

Tanaka S, Seki K, Hanakawa T, Harada M, Sugawara SK, Sadato N, Watanabe K, Honda M (2012). Abacus in the brain: A longitudinal functional MRI study of a skilled Abacus user with a right hemispheric lesion. Front. Psychology; 3(315): 1 -13. [Accessed on 22 Sep 2017]. Available from: https://doi.org/10.3389/fpsyg.2012.00315 https://doi.org/10.3389/fpsyg.2012.00315

Tanridiler A, Uzuner Y, Girgin U (2015). Teaching and learning mathematics with hearing impaired students. Anthropologist; 22(2): 237-248. [Accessed on 16 Sep 2017]. Available from: https://doi.org/10.1080/09720073.2015.11891874 https://doi.org/10.1080/09720073.2015.11891874

Traxler CB (2000). The Stanford achievement test, 9th edition: national norming and performance standards for deaf and hard-of-hearing students. Search Results Journal of Deaf Studies and Deaf Education; 5(4): 337-348. [Accessed on 22 Sep 2017]. Available from: https://doi.org/10.1093/deafed/5.4.337 https://doi.org/10.1093/deafed/5.4.337

Vani R (2014). Gender discrimination in Indian academics - A critical review. International Journal of Management and Social Science Research Review; 1(4): 147-153. [Accessed on 16 Sep 2017]. Available from: http://ijmsrr.com/downloads/31102014IJMSRR%2021.pdf

Vita AC, Kataoka VY (2014). Blind students' learning of probability through the use of a tactile model. Statistics Education Research Journal; 13(2): 148-163. [Accessed on 17 Sep 2017]. Available from: https://iase-web.org/documents/SERJ/SERJ13(2)_Vita.pdf

Wanjiru MM, Munyi CW, Murugami M (2014). Pedagogical challenges facing mathematics teachers of learners with visual impairment at Thika primary school for the blind, Kiambu county (Unpublished master's thesis). Kenyatta University. [Accessed on 17 Sep 2017]. Available from: http://ir-library.ku.ac.ke/bitstream/handle/123456789/11179/Pedagogical%20challenges%20facing%20mathematics%20teachers%20of%20learners%20with%20visual%20impairment......pdf;sequence=1

Wood DJ, Wood HA, Howarth SP (1983). Mathematical abilities of deaf school-leavers. British Journal of Developmental Psychology; 1: 67-73. [Accessed on 13 Sep 2017]. Available from: https://doi.org/10.1111/j.2044-835X.1983.tb00544.x https://doi.org/10.1111/j.2044-835X.1983.tb00544.x

Zarfaty Y, Nunes T, Bryant P (2004). The performance of young deaf children in spatial and temporal number tasks. Journal of Deaf Studies and Deaf Education; 9(3): 315-326. [Accessed on 16 Sep 2017]. Available from: https://pdfs.semanticscholar.org/fccc/44a14bf9197d032f27c570e85bb5c0aed24b.pdf https://doi.org/10.1093/deafed/enh034