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Research Paper

Effect of Abacus Mental Arithmetic Training on Problem-Solving Ability of Students with Hearing Loss

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ABSTRACT

The purpose of this study was to experiment if problem-solving ability of students with hearing loss is at variance by imparting the Abacus Mental Arithmetic Training. The research sample comprised of ninety 3rd and 4th grade students with hearing loss from special schools in Mumbai and its sub-urban districts in India. A quazi experimental pre-test/post-test non-equivalent control group design was employed. The problem-solving abilities were studied before and after the Abacus Mental Arithmetic Training using Porteus Maze Test. Results of the T-test - Assuming Equal Variances indicates that the problem-solving ability of the experimental group instructed via Abacus was superior as compared to the control group instructed using the conventional method.

Keywords: *Abacus, Problem-Solving Ability and Students with Hearing Loss*

Problem-solving is not just an activity to solve a problem; rather it is a complex activity involving cognition, behaviour, and attitude (Foshay & Kirkley, 2003). Krulik and Rudnick (as cited in Luckner & McNeill 1994) described problem-solving as the "means by which we use previously acquired knowledge, skills, and understanding to satisfy the demands of unfamiliar situations." Mayer (1983) defined problem-solving as some processes with phases that require problem solver to be able to find a connection between experience (schema) that he or she already owns, with the problem he or she faces and is able to do something to solve the problem.

Problem-solving is obligatory and forms a part of the daily routines. Kamaruddin and Hazni (as cited in Kunchon, 2012) also recommended that the problem-solving ability is especially important for students as they can improve their learning ability. According to Mayer (1990) problem-solving is a complex cognitive process wherein a problem solver transforms a given situation into a goal situation when no obvious solution method is available to solve the problem. This definition focuses on three aspects of problem-solving:

1. Problem-solving is a cognitive function occurring internally in the mind of the learner.
2. It is a process involving a series of mental manipulations and computations.
3. It has a direction and an aim and the learner aims to achieve the goal.

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Clearly then, problem-solving ability incorporates insights, strategies and techniques facilitating mental representations and manipulations to arrive at a solution and hence, it could be assumed as a Mental Mechanics in Arithmetic.

Mental arithmetic and problem-solving are not linear processes. Their key components include thinking, reasoning, creativity, flexibility, dispositions and discernment of the problem itself. Language being the prerequisite for most of the cognitive activities, children with linguistic paucity are at a distinct disadvantage when it comes to mathematical mental problem-solving abilities. This is because the acquisition and use of a knowledge base for problem-solving is dependent on language and thinking skills (Smiley, Thelin, Lance & Muenchen, 2009) which is an exigent task for children with hearing loss. As affirmed by deVillers and deVillers, (1978); Erber, (1982); Ling, (1984); McAnally, Rose, and Quigley (1994) the most debilitating aspect of hearing impairment is not the loss of hearing, but the subsequent language impairment resulting from insufficient auditory input. Diminished language leads to diminished content knowledge of the subject and hence, these students experience difficulties in academics. Delays in language also hampers the ability to think critically about situations. As critical thinking skills such as analyzing, discriminating, information gathering, logical reasoning, predicting, and knowledge transforming are vital to problem-solving (Scheffer & Rubenfel, n.d.), so the difficulties in problem-solving can be ascribed as a consequence of language difficulties resultant of hearing loss.

Learning and problem-solving

Lambdin (2003) describes “problem-solving as somewhat recurring and co-dependent with understanding, because understanding enhances problem-solving and learning through problem-solving develops understanding” (p.7). Murray, Olivier and Human (1998) suggest that problem-solving is the vehicle for learning as it comes before the teaching begins. This occurs when students grapple with problems for which they have no routine methods of solution. Problem-solving is the manifestation of constructivist learning which benefits knowledge of scholastic subjects especially mathematics. This is because young students learn best and retain information through constructing their own knowledge. This is a premise put forth by prominent constructivist thinkers like Bruner, Piaget and Vygotsky who believed that children by nature are explorers and are capable of critical thinking for problem-solving.

Bruner's Discovery model of learning suggests that students attain knowledge when problem-solving is contextualised rather than taught by using traditional transmission methods. Tangible hands-on method is suggested in Bruner's model of learning, as he believed that learning begins by touching, feeling and manipulating (Brahier, 2009). The three principles associated with Bruner's Discovery Learning Theory includes; experiences especially mathematical problem-solving in contexts coupled with students willingness to learn, structured instructions with spiral organization designed to facilitate extrapolation and going beyond the provided information.

Piaget's Cognitive Development theory (1958), and later the conception of equilibration (1985) also proposes the idea of discovery learning where children learn best by actively exploring. According to Piaget, assimilation, accommodation and finally the equilibration which is the force driving the learning process requires an active learner, not a passive one, because problem-solving skills cannot be taught, they must be discovered.

The Piagetian theory, recommends that learning in classrooms needs to be student-centred where the role of the teacher is to facilitate learning, rather than a direct tuition. Therefore, teachers should encourage the following within the classroom:

- Focusing on the process of learning, rather than the end product of it.
- Using active methods that require rediscovering or reconstructing "truths."
- Using collaborative, as well as individual activities (so children can learn from each other).
- Devising situations that present useful problems, and create disequilibrium in the child.
- Evaluating the level of the child's development through suitable tasks.

Vygotsky, a social constructivist, also disproved the traditional transmissionist or instructionist model of learning in which a teacher ‘transmits’ information to the students. Vygotsky's theory promotes contextual learning in which students play an active role. The role of a teacher and the student are altered, as a teacher needs to collaborate with the students in order to facilitate the construction of meaning in the students. Vygotsky's (1962) discussion of problem-solving experiments with manipulatives such as blocks of various shapes, sizes, and colours reveals that first children experience active problem-solving with others; then s/he gradually functions independently and internalizes the concept. While bridging the zone of proximal development (ZPD), Vygotsky suggests scaffolding by adults and mentors. He also emphasises that students need to have significant interactions with materials so as to reach a heightened state of understanding.

Constructivism for learning and problem-solving is thus process driven. It relies on children's own and unique understanding and emphasizes on how children 'come to know' (Begg, 1995). This knowing and the progression of perceptive understanding for concept formation is facilitated by language in all children regardless of hearing status. Meadow-Orlans (1980) also affirm that mathematical concepts can be learnt by deaf/hearing-impaired children in the same sequence and manner as their hearing peers. This raises the issue of differences in the hearing and deaf children's learning environment which facilitates their ‘coming to know’. According to Ray (2001) good communication skills are required for engagement in mathematical processes such as problem-solving, developing logic, reasoning and communicating mathematical ideas in children. This provides an explanation as to why deaf children lag behind in problem-solving and other cognitive abilities. Besides direct interactional learning for problem-solving, hearing children get a lot of opportunities for incidental learning which does not occur in case of children with hearing loss. According to Carney and Moeller (1998) reduction in incidental learning results in negative consequences of knowledge acquisition. The difference in the mathematical and problem-solving abilities of children with and without hearing loss is thus a result of two factors namely; communicating environment and incidental learning. Pau (1995) also makes a supportive observation in this regards. Many deaf/hearing-impaired children experience experiential deficits and different learning environments. To sum up the discussion of learning, reflections of Ansell and Pagliaro, (2006); Hyde, Zevenbergen, and Power, (2003); Kelly et al., (2003) are vital. According to them, deaf students experience difficulty in math problems due to a combination of linguistic, cognitive, and experiential factors.

LITERATURE REVIEW; A RATIONALE FOR THE PRESENT STUDY

Problem-solving ability, a necessary skill for academic achievement, is perhaps negatively impacted by the disability of hearing impairment (World Health Organization [WHO], 2001). However, the body of literature about problem-solving skills in children with hearing loss is small (Smile et al., 2009). Numerous studies indicate that, on the average, children with hearing impairment lag behind their hearing peers in academic accomplishment (Brackett & Maxon, 1986; Hine, 1970; Karchmer & Mitchell, 2003; Meadow Orleans, 2001; Moores, 2003; Marschark, 2006; Nunes & Constanza, 1998; Peckham, Sheridan, & Butler, 1972; Paul & Young, 1975; Quigley & Thomure, 1968; Steer et al., 1961; Swanwick, Oddy, & Roper, 2005; Trybus & Karchmer, 1977). Also, Deaf students in various countries have scored poorly on mathematics assessments (Leybaert & Van Cutsem, 2002; Mitchell, 2008; Nunes & Moreno, 1998; Pagliaro, Foisack, & Kelly, 2010; Swanwick, Oddy, & Roper, 2005; Traxler, 2000; Wood, Wood, Griffiths, & Howarth, 1986) including tasks involving computation and reasoning (Allen, 1995) logical thinking (Marschark & Everhart, 1999), and problem-solving (Ansell & Pagliaro, 2006). Some researchers have argued that poor performance in mathematics by deaf or hard of hearing students is because these students do not have sufficient opportunities to engage in challenging problem-solving activities. Like some general education instructors, teachers of deaf or hard of hearing students often focus more on practice or drill exercises that do not require much higher-level thinking skills, but provide limited instruction in problem-solving (Dietz, 1995; Pagliaro, 1998, 2006).

Traditionally, mathematics education has placed more emphasis on fixed symbolic procedures by memorization and imitation rather than thinking, and reasoning (Battista, 2001). Recently, however, the current reform movement in school mathematics has called for changes in teaching practices that move towards the constructivist teaching paradigm (Battista, 2001; Pape & Smith, 2002), which includes manipulatives. Abacus has been in use as a tool for teaching and developing mathematical concepts. Recently it has been used for developing problem-solving abilities also. According to Hayashi (2000); Kawano (2000) and Amaiwa (2000) Abacus training for the children in early ages helps children to develop their problem-solving abilities. Rubenstein (2001) also established that, students who learn Abacus, develop their problem-solving skills. This is because children experiment and evolve different techniques and methods to solve a problems while using the abacus. Lean and Lan (2007) also observed that the children who had undergone Abacus mental training were more skilled to undertake problem-solving as compared to other children who did not have such training. On his work Kara (2013) stated that the Abacus Mental Arithmetic Training is a creative thinking program which positively effects the development of mathematical problem-solving skills. It can be concluded that Abacus training has multiple benefits enhancing various dimensions of cognitive abilities. From the literature reviewed with respect to the mathematics reform movement and deafness, it is seen that strong recommendations have been made by the National Action Plan for Mathematics Education Reform for the Deaf (NAPMERD; see Dietz, 1995) for change in mathematics education supporting the National Council of Teachers of Mathematics (NCTM) standards and emphasizing the importance of problem-solving (Pagliaro, 1998, 2006; Pagliaro & Ansell, 2002).

While independent literature with regards to deafness and lower achievement in mathematics, constructivism for learning math's, and abacus for problem-solving, are available, it will be beneficial to see the outcomes of the three dimensions integrated in a single study. The other rationale of the present research is based on a study conducted in the

Indian context. Frankand and Barner (2011) conducted research on Indian students and concluded that mental arithmetic i.e. the computations of practiced users (but not those of control participants) are relatively insensitive to verbal interference, consistent with the hypothesis that mental arithmetic is a non-linguistic format for exact numerical computation. Since children with hearing loss also have lower linguistic competencies, the present enquiry was designed to extend the understanding whether Abacus Mental Arithmetic Training enhances the Performance intelligence reinforcing the problem-solving ability?

Design of the Study

The basic aim of this study was to investigate whether abacus mental arithmetic training is beneficial in enhancing the Problem-Solving Ability of students with hearing loss. It adopted a quasi-experimental pre-test / post-test non-equivalent control group design and t-test assuming equal variances was used to test the null hypotheses. The sample was drawn from six special schools randomly selected from a pool of twelve special schools for children with hearing loss having sufficient number of 3rdand 4th graders.

The sample belonged to the population of the primary special schools from Mumbai and sub-urban areas recognised by the Social Welfare Department of the Govt. of Maharashtra. Ninety students recruited for the study were assigned to the control and experimental groups on the basis of availability of 3rd and 4th standard student's in one single special school. This was done for nullifying the threats of different school backgrounds and for the sake of conducting the training sessions. Only one special school out of the six had both 3rd and 4th grades students totaling to 35 while other special schools had either the 3rd or the 4th grade.
Ravens' progressive Matrices Test having reliability coefficient of 0.84 and validity of 0.91 was used to ascertain the normalcy of the control and experimental groups, which is as follows:

Table 1 Ravens' progressive Matrices Test of assigning students to Experimental and Control group

Name of the Test	Group	N	Mean	SD	't' value		Significant level at .05
					Cal. value	Crit. value	
Standard Progressive Matrices	Experimental Group (EG)	35	25.54	9.15	1.03	1.98	Non - Significant
	Control Group (CG)	55	27.63	9.54			

Note. EG = Experimental Group and CG = Control Group

No significant difference within the group implies that the two groups of students had similar cognitive abilities. The distribution of the sample is as follows:

Table 2 Sample distribution

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

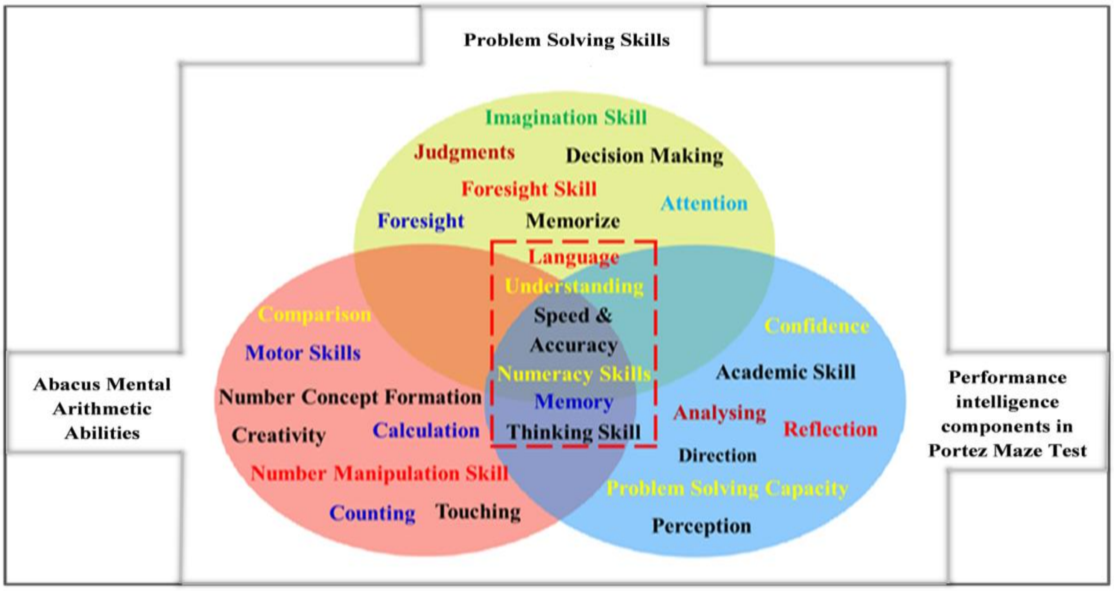
Note. EG = Experimental Group and CG = Control Group

Procedure

The instrument used for data collection was Porteus Maze Test developed by Porteus (1950). It is a test of measuring the Performance intelligence. The Porteus Maze Test has a reliability coefficient of 0.77 and validity of 0.65. It is a non-verbal test designed to examine use of planning, patience, foresight, impulsivity and mental alertness in young children. It is recommended for measuring performance intelligence of children between 8 to 14 years (Prosek, 2009). Because the test is non-verbal, it is most suitable for the subjects of the present study who were children with hearing loss and whose age range was between 8 to 14 in both experimental and control groups.

The treatment to the experimental group using Abacus Mental Arithmetic Training and use of Porteus Maze Test for studying the gain in problem-solving was predominantly chosen for the present experiment as the reviewed literature portrays a lot of commonalities of the skills. The same is diagrammed in Figure 1 below:

Figure 1. Interconnected skills of Problem-solving, Abacus Mental Arithmetic and Components of Performance Intelligence in Porteus Maze Test



The pre and post-test was individually administered to children from both groups, however, the training sessions of abacus to the experimental group was imparted collectively. Each subject of the experimental group was provided an independent abacus slate for the purpose of instructions. The training was conducted for eight months in the special school to which the experimental group belonged. The pre and post-test of the control group was also conducted in their respective special schools simultaneously.

RESULTS AND DISCUSSION

Table 3 The gain in the problem-solving ability of experimental and control group

Variable	Group	N	Pre Test	Post Test	Mean Gain	SD	't' value Cal. value	't' value Crit. value	Significant level at .05	Null Hypothesis
Problem solving ability	*EG	35	20.97	27.42	6.45	2.16	07.64	1.99	Significant	Rejected
	**CG	55	21.90	25.36	3.45	1.55				

Note. EG = Experimental Group and CG = Control Group

Figure 2. Comparison of the mean gain scores of the experimental and control group

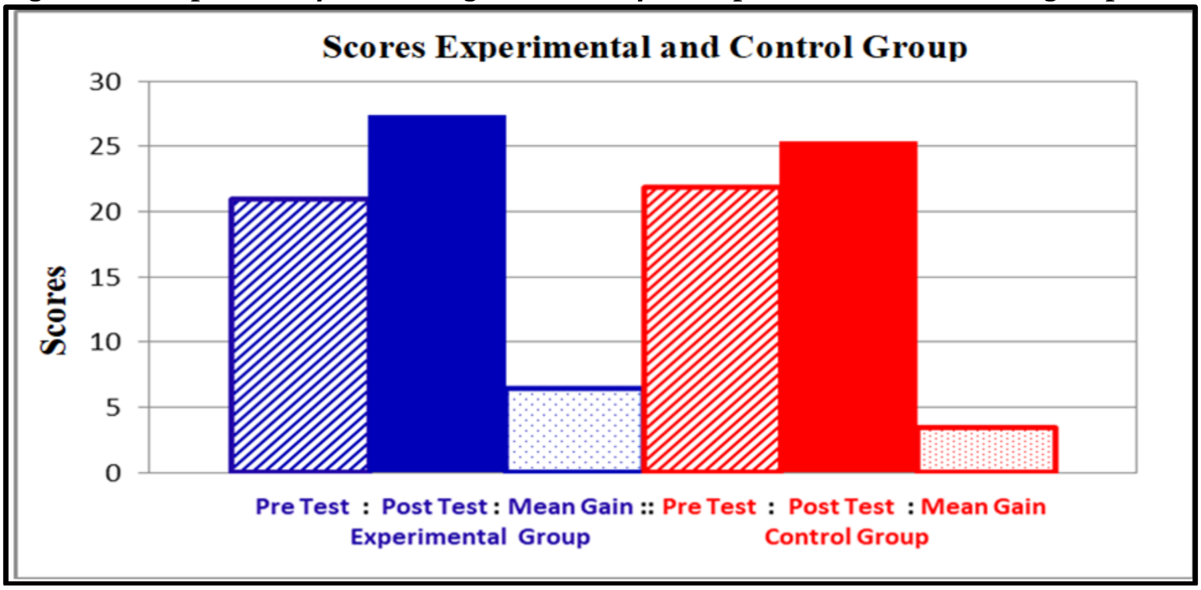


Table 3 illustrates that the calculated ‘t’ value is greater than the critical ‘t’ value (07.64 > 1.99). Hence, the null hypothesis that ‘There is no significant difference between the mean gain scores of the problem-solving ability of students in experimental and control groups’ does not hold well. The mean of the experimental group being greater than that of the control group (6.45 > 3.45) shows that the abacus mental arithmetic was significantly improves the problem-solving ability in the experimental group. The alternate hypothesis formulated i.e. “There will be a significant difference between the mean gain scores problem-solving ability of students in experimental and control groups.” was therefore retained.

The sample of the present study was drawn from the special schools of the district of Mumbai and its sub-urban areas in India which still has sizable number of children enrolled. This is in spite of the Government policy promoting inclusive education in mainstream schools. According to Easterbrooks and Baker (2002) language acquisition is and has been the fundamental focus of educating children with hearing impairment. Hence, the special schools for children with hearing loss provide a very intensive language based instructional program. The class size in special schools are smaller and so ample time and opportunity is devoted to curricular activities that includes auditory training, developing oral or manual communication skills and reading instructions. Not much time is hence dedicated to instructional strategies using manipulatives for subjects such as Arithmetic. In a study conducted by Jadhav and Gathoo (2017) in the same geographical area in India, concludes that the awareness and functional knowledge about abacus and its use for Arithmetic teaching among teachers in special schools was less and hence the teachers were not using it for classroom instructions. On similar lines the National Science Foundation (2004) also observes that acquisition of mathematical knowledge through problem-solving and with manipulatives is considered time-consuming and laborious by many classroom teachers and they hesitate to use such devices.

The incorporation of manipulatives such as abacus for Arithmetic instructions has dual advantages. According to the reviewed literature, it not only increases speed and accuracy of numerical ability, but also enhances the problem-solving abilities of children, the same can be ascertained from the similarities of the skills required in both these areas as depicted in Figure 1. This justifies the outcome of the present experimental study illustrating improved performance of children in the experimental group on the problem-solving ability on undergoing the Abacus Mental Arithmetic Training.

IMPLICATIONS, RECOMMENDATIONS AND CONCLUSIONS

The findings of the present study are vital for planning the classroom instructional techniques and strategies especially when there are divergent group of learners. Instructions using manipulatives especially for children with hearing loss should be encouraged as language deficiencies which otherwise creates barriers in acquisition of knowledge and thinking through deeply can be intuitively bolstered. Reiterating the educational theories of constructivism mentioned previously in this article, the findings of the present study also proves that children with hearing loss benefit from use of mathematical manipulatives.

Supporting evidence from Reusser (2000) states that "children are active individuals who genuinely construct and modify their mathematical knowledge and skills through interacting with the physical environment, materials, teachers, and other children." This is thought to benefit the larger picture of daily living skills. Kelly (2006) also connects this to everyday situations in people's lives. In her opinion all of us do use problem-solving on a regular basis, which appears to be connected to some form of tool, tangible, or manipulative (tires, air pressure gauges, cereal types, sizes, and characteristics, etc.). She recommends that the children in elementary classes should be guided to apply the performance-based knowledge gained through use of manipulative-based materials, into the creation of models which are, successively connected to numbers and algorithms in higher grades. Van de Walle (2004) also shows that problem-solving is an important instructional strategy which not only engages students in important mathematical learning; but also permeates in life in general. Furthermore, if we aspire that children learn to think deeply and critically about real mathematics and its application so also use thinking comprehensively in real life situations, we must also teach and assess their knowledge in different ways. These divergent ways would allow them to portray a real understanding of the tasks being tested. Additionally, teachers need to see beyond merely the correct or incorrect answers. In fact, according to Van de Walle (2004) teachers need to garner a holistic and more diversified view of each child's mathematical understanding as this would help to develop quicker and more fully in classrooms where a problem-based approach is in place.

In summary, through the present research it is seen that mental arithmetic training using a abacus as a manipulation device fosters problem-solving ability of children with hearing loss. It is hence concluded that a wide range of meaningful mental mathematical experiences that are visually engaging and hands on, needs to be provided to children in schools. Many things in our everyday lives have a mathematical basis, so engagement in mathematical processes such as problem-solving will help to develop logic and reasoning in case of children with hearing loss.

Children with hearing loss, are not cognitively impaired and if proper inputs are given, they are capable of learning and problem-solving similar to their hearing counterparts. Building on this premise opportunities for application of knowledge to build new knowledge and apply it to for enhancing problem solving abilities needs attention. This should be embedded in the curricula of children in schools at all level as well as in the teacher preparation programs of special and inclusive education as well.

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