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EFFECT OF USE OF ASSISTIVE DEVICES ON ADAPTIVE REASONING, PROCEDURAL FLUENCY AND CONNECTIONS OF MATHEMATICS WITH OTHER SUBJECTS OF FOURTH GRADERS WITH DYSCALCULIA

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Abstract
The study with 29 students having dyscalculia utilized pre-test post-test control group design. The experimental group was given remediation by use of assistive devices while control group was taught through traditional method. Findings revealed that the subjects in assistive devices group showed significant improvement from pre-test to post test in mathematical skills (Adaptive reasoning, Procedural fluency and connections of mathematics with other subjects).

Keywords: Assistive devices, adaptive reasoning, procedural fluency, connections of mathematics with other subjects, dyscalculia

Introduction and Rationale
Dyscalculia has been defined as a specific mathematical learning disorder (MLD), where the mathematical ability is far below expected for a person's age, intelligence, and education. Mathematics gains importance because of the importance of mathematics in humans' life and benefits to scientific life. Mathematics teaching at begins pre-school, primary school and then it continues during a big period. Teachers, parents and students are often aware of the fact that there are a number of persons with special difficulties in learning mathematics. Pupils with mathematics learning disorders may feel uncomfortable in learning situations, unless they are being treated in a way that facilitates their learning. In order to give the proper education to a pupil with dyscalculia it is essential to understand the most suitable ways in which students with learning disabilities can acquire mathematical understanding, which is closely associated with abstract thinking.
Various studies found different incidence. Lewis, Hitch and Walker (1994) found prevalence of dyscalculia of 1.3% among children aged 9-10 years. Studies of Kosc (1974), Badian (1983), Gowramma (2000), Shalev and Gross-Tsur (2001), Koumoula, Tsironi, Stamouli, Bardani, Siapati and Graham (2004), Guillemot (2010) and showed that the prevalence of developmental dyscalculia in these countries is about 3 to 6.5%. Geary (2006) investigated Characteristics and Potential Influence of dyscalculia at an Early Age. Between 3 and 8% of school-aged children will show evidence of dyscalculia.
Researchers explored to enhance mathematics understanding among dyscalculics through various interventions. Jha (2012) attempted to disclose the fundamental reasons of students' poor achievement in mathematics through analysis of the levels of their abilities using Newman Procedure. The data recommended that most of students' errors occurred at comprehension as well as at the transformation level.
Beygi, Padakannaya and Gowramma (2010) investigated the impact of remedial intervention on students' performance with dyscalculia in teaching addition and subtraction. Forty male students with dyscalculia (20 in experimental, and 20 in control groups) from fourth and fifth grades in Arak, Iran were the participants. The experimental groups received are medial program in addition

to their regular classroom teaching (every other day). Data analysis indicated a significant increase in the subtraction and addition performance after remedial intervention.
Chauhan (2004) investigated the effectiveness of different strategies for remediating dyscalculia in primary school children. She used three different kinds of remedial treatments i.e. cooperative learning, clinical mathematics interview and error detection and correction (error analysis). Results shown that cooperative learning, clinical mathematics interview and error detection and correction, all the three strategies contribute significantly for the remediation of dyscalculia for grade 2 and 3 students. Grade 2 students have improved more than grade 3 students.
Shih (2005) investigated effects of number sense intervention on second-grade students with mathematics learning disabilities. The purposes of this study were to investigate the effectiveness of number sense instruction on fact retrieval performance of students with math learning disabilities. The results showed that students who received repeated practice followed by number sense instruction had better initial performance on fact retrieval.
Ramaa and Gowramma (2002) described the procedures adopted by two independent studies in India for identifying and classifying children with dyscalculia in primary schools. For determining the presence of dyscalculia both inclusionary and exclusionary criteria were used. When other possible causes of arithmetic failure had been excluded, figures for dyscalculia came out as 5.98% (15 cases out of 251) in one study and 5.54% (78 out of 1408) in the second. It was found in the latter study that 40 out of the 78 (51.27%) also had reading and writing problems.
Rozario and Kapur (1992) used intervention strategies to remediate problems in four basic operations progressing from concrete level to abstract level. Results indicated that there was a significant improvement in the performance of arithmetic tests after remedial education.
Ramaa (1990) revealed that difficulty of the students with dyscalculia in concrete situations would definitely influence their performance in tasks dealing with numbers which are relatively most abstract.
In rapidly changing societies, the individuals need to accurately understand events, phenomena and opinions and they need to find creative new solutions to lead an effective and efficient life changing living conditions also change human profiles. If it is emphasized that learning mathematics is easy, permanent, and beneficial and fun, then children will not be afraid of mathematical concepts thinking that they can learn mathematical concepts. A child will be willing to learn mathematics when he/she can see the underlying aim in mathematical concepts and when he/she understands the method to learn mathematics, self-confidence of a child and awareness of his/her learning capabilities increase his/her cognitive learning potential. For solving these problems one can use some strategies and technology devices. Such as metacognition strategies and assistive devices can be used to remediate mathematical learning disorders.
Students with dyscalculia struggle with too rapid pacing of introducing new mathematics concepts, and insufficient examples, explanations, practice, and review in general education classrooms. For dyscalculia student's technology can offer a variety of individualized mathematics instructions to meet their special learning characteristics and to ensure their successful mathematics achievement in general education settings. The Technology-Related Assistance for Individuals with Disabilities Act was designed to enhance the availability and quality of assistive technology (AT) devices and services to all individuals and their families throughout the United States. Assistive technology (AT) device means any item, piece of equipment, or product system, whether acquired commercially off the self-modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child or people with a disability. AT includes of software and hardware parts. There is special software that are organized and constructed by researchers for dyscalculia students.
In the present research the researcher attempted to improve the mathematical skills of dyscalculic students with the effective use of assistive devices.

Objective

The objective of present paper is to examine whether children with dyscalculia will improve in adaptive reasoning, procedural fluency and connections of mathematics with other subjects when given remediation by assistive devices.

Assistive devices and adaptive reasoning, procedural fluency and connections of mathematics with subjects: Review

Hypothesis 1: The children with dyscalculia will improve significantly in adaptive reasoning after administration of assistive devices technique of intervention.

Assistive technology and adaptive reasoning

Following is a brief account of studies related to assistive technology and adaptive reasoning:

Lokken (2012) identified the impact of teaching reasoning strategies on multiplication and division fact fluency, problem solving skills and mathematical anxiety to increase conceptual understanding in mathematics. The findings of this study showed that teaching reasoning strategies for conceptual understanding increased fact fluency and problem-solving skills.

Bressette (2010) investigated the comparison of fourth grade students with learning disabilities and their nondisabled peers on mathematics reasoning performance of 3 sub skill areas of strategic competence, calculation accuracy, and communication clarity. The findings indicated that intensive instructional interventions in mathematics were needed to remediate mathematical reasoning deficits of 4th grade students with SLD.

Lack (2010) investigated K-12 standards-based mathematics reform embraced a greater emphasis on students' ability to communicate their understandings of mathematics by utilizing adaptive reasoning (i.e., reflection, explanation, and justification of thinking) through mathematics discourse. Cross-case findings suggested that (a) students' willingness to contribute to task discussions was related to their goal orientations as well as the degree of social risk perceived with providing incorrect solutions before their peers; and (b) differences between the kinds of peer and teacher interactions that low- and high-performers engaged in were directly related to the types of challenges they faced during discussion of these tasks.

Analysis of review of studies by Lokken (2012), Bressette (2010) and Lack (2010) indicated that intensive reasoning strategies are needed to strengthen mathematical reasoning. All of them did not focus in one particular direction but we can conclude from above studies that reasoning skills of children can be remediated with the help of some reasoning strategies and that will make a significant difference in the performance and motivation levels of children.

Hypothesis 2: The children with dyscalculia will improve significantly in procedural fluency after administration of assistive devices technique of intervention.

Assistive technology and procedural fluency

Following is a brief account of studies related to assistive technology and procedural fluency:

Bautista (2013) investigated students' procedural fluency and written-mathematical explanation on constructed response tasks in physics. Test results confirmed the assumptions of the study: the students' procedural fluency is dependent to their mathematical ability, both algebraic and trigonometric, while their written-mathematical explanation is associated to their English ability.

Foster (2013) investigated opportunities for developing procedural fluency in mathematics. He illustrated the tactic in three central areas of the high-school mathematics curriculum: plotting Cartesian coordinates, solving linear equations and performing enlargements. In each case, extensive practice of important procedures took place alongside more thoughtful and mathematically creative activity.

Tseng (2012) investigated conceptual and procedural knowledge in mathematics education in the case of law of exponents. In this study, a detailed research into students' understanding of conceptual knowledge vs. procedural knowledge over the law of exponents has been conducted.
Khairani and Nordin (2011) assessed three of the strands, namely, conceptual understanding, procedural fluency, and strategic competence among 14-year-old students. Results from Rasch Model calibration showed that students were most proficient in conceptual understanding followed by strategic competence and procedural fluency.
Samuelsson (2010) examined the effect of two differently structured methods, traditional and problem-solving, of teaching children mathematics. In order to develop aspects of self-efficacy, the results showed that pupils would better benefit from a traditional curriculum. Boys and girls who have been taught with similar methods perform equivalent in both the traditional and the problem-solving group.
Wu (2008) assessed 491 Chinese sixth graders' mathematics proficiency reflected in conceptual understanding, procedural fluency, and competence in word problem applications using the model – strategy - application (MSA) approach. The results revealed that a higher level of computation did not lead Chinese students to a deep understanding of fractions and decimals. The study suggested achieving a balanced way of teaching and learning mathematics through the MSA approach.
Analysis of review of studies by Bautista (2013), Foster (2013), Tseng (2012), Khairani and Nordin (2011), Samuelsson (2010) and Wu (2008) indicate that procedural fluency is a significant strand in the mathematics. All of them did not focus in one particular direction but we can conclude from above studies that teachers should make balance between procedural fluency and other skill of mathematics. Procedural fluency can be taught by assistive devices with a balanced approach.

Hypothesis 3: The children with dyscalculia will improve significantly in making connections of mathematics with other subjects after administration of assistive devices technique.

Assistive technology and connections of mathematics with other subjects
Following is a brief account of studies related to connections of mathematics with other subjects and dyscalculia:
Omaha and Nebraska (2011) investigated a study of mathematical connections through children's literature in Vth and VIth grade classroom. They discovered that the use of children's literature engaged the students into making mathematical connections. As a result of this research, the quality of student work improved, and they planned to incorporate more children's literature into my mathematics lessons.
Mwakapenda and Dhlamini (2010) presented findings from a pilot study that investigated the extent to which teachers make connections between mathematical concepts and concepts from other disciplines. The analysis revealed that the kinds of connections teachers made are closely tied to teachers' disciplines of specialization. The findings suggested that for some teachers, though desirable, it might not be feasible to require them to make connections with disciplines that were not within their areas of specialization.
Wilburne and Napoli (2008) investigated connections of mathematics and literature. This study examined the influences on eight pre-service elementary school teachers' beliefs and knowledge of teaching mathematics through literature. Teacher education programs can benefit from replications of this study.
Furner and Kumar (2007) investigated the integration of mathematics and science. This paper explored the question, should we integrate mathematics and science in reforming science education? Considerations and recommendations for mathematics and science integration are addressed.
Quan (2006) determined whether there was a significant difference between the middle school at-risk students who have participated in the Model Arts Program for two years and middle school

at-risk students who have not participated in the Model Arts Program for two years. Females, as a group, performed better than males on their sixth grade CST tests. However, the treatment group outperformed the control group after a second year of the program in English-Language Arts and Mathematics.

Analysis of review of studies by Omaha and Nebraska (2011), Mwakapenda and Dhlamini (2010), Kailikole (2009), Wilburne and Napoli (2008), Furner and Kumar (2007), Michelsen (2006) and Quan (2006) indicate that mathematics plays a vital role in making connections with other subjects and facilitate learning of language, science and arts. Teacher education programs can benefit from the given replications. Connections of mathematics with other subjects have improved significantly by usage of assistive devices.

METHOD

Design

An experimental design named pre-test post-test control group was used.

Sample

The data were initially obtained from 720 students, out of 720, 52 children were found with mathematical disorder. Here, incidence of mathematical disorder is found to be 7.22 %. In first phase, report cards of 720 fourth graders were observed to check the discrepancy between the achievement of mathematics and languages. A list of 80 students who had discrepancy in the achievement of mathematics and languages was prepared by the researcher. In second phase, teacher referral forms were distributed to all class teachers of fourth grade students for listed students. On the basis of teacher referral forms 70 students were further observed for the characteristics of dyscalculia. Raven's Progressive Matrices was also administered just to eliminate low intelligence on 70 children identified in the second phase. In third phase, 68 students who got score of 23 and above in Raven's Progressive Matrices were selected. A score of 23 indicates average performance.

In next phase, Diagnostic test for mathematics disorders for fourth graders was administered on 68 students to confirm the specific mathematical disabilities among children. In this process the researcher identified 52 children with dyscalculia. The schools which had highest number of dyscalculic children were taken for experimental research. The subjects were divided into two groups viz. one experimental (assistive devices) and one control group (traditional teaching) in which 29 students were taken.

Tools

Identifying tools

- **Report cards**

  In the identification process, first step was to observe the report cards of the students. The scores of students having more than 25% discrepancy between language and mathematics performance in the final report card (which includes midterm and final exam) were observed and shortlisted for further research.

- **Teacher referral forms**

  Researcher prepared two sections of the teacher referral form, one is prepared for the language teachers and another is meant for mathematics teachers. This information helps in planning; the strategies to be used for teaching and behaviour judgement of subjects. The information was used later at the time of treatment.

- **Coloured progressive matrices (CPM)**

  Raven's coloured Progressive Matrices or CPM (Raven, Raven & Court, 1998) is a nonverbal group test typically used in educational settings. This tool is known for assessing the degree to which children can clearly think or the level to which their intellectual functions have deteriorated.

4.3.1.4 Diagnostic test of Mathematical Disorder for Fourth Graders

This tool was constructed and standardized by researcher**.** It includes memory (long term and short term), number operation difficulties, and language processing difficulties, attention deficits, visual problems, closure and generalization. This tool was used to identify students who were shortlisted after assessment via coloured progressive matrices.

Assessment tools

- **Tool on Adaptive Reasoning**

  Adaptive reasoning refers to the capacity for logical thought, reflection, explanation, and justification (Kilpatrick, Swafford & Findell, 2001). This is achievement test consisting 28 items on capacity for logical thought, reflection, explanation, and justification and ability to make connections between diverse mathematical concepts. Each dimension has its subparts. Capacity for logical thought includes generalization, operational sense, understanding of equivalence and comparison, coding decoding and representation. Reflection includes relations, location and movement, rounding decimals, estimated sums and differences and filling the missing number. Explanation includes visual representation, properties of 2-D geometry, classification, national and international place value system and expansion of numbers. Justification includes draw conclusions, demonstration, and description and analysis. Ability to make connections between diverse mathematical concepts includes vocabulary and mathematics language, usage of symbols and relationship of fraction and decimal.

- **Tool on Procedural Fluency**

  Procedural fluency refers to knowledge of procedures, knowledge of when and how to use them appropriately, and skill in performing them flexibly, accurately, and efficiently (Kilpatrick, Swafford & Findell, 2001). This is an achievement test consisting 28 items on knowledge of facts and procedures, relationship of addition and subtraction, computation, knowledge of multiples, interpretation of division, relationship of multiplication and division, estimation strategies, expansion of knowledge of basic facts, understanding of factors and multiples, development of thinking, knowledge of even-odd and prime-composite numbers, knowledge of HCF & LCM, basics of unitary method, measurement of time & distance, measurement of money and units, procedure of reading and recording time, time conversion, interpretation of calendar, recognition of shapes, composing, decomposing, solve variety of problems and increasing knowledge.

- **Tool on Connections of mathematics with other subjects**

  Connections make mathematics more meaningful and make learning easier. Recognizing and establishing connections can greatly assist students in their efforts to solve problem, reason, and communicate about mathematics. This is an achievement test consisting 33 items on connection with science, literature and arts, social studies and recognization and application of mathematics outside mathematics. Each dimension has its subparts. Connection with science includes measurement of weight, length, litre, area and perimeter and conversion of units. Connection with literature and arts includes measurement of time, knowledge of geometrical ideas and extending patterns. Connection with social studies includes representation and interpretation of data and connection with sports. Recognize and apply mathematics outside of it includes generation and analysis of patterns and their application in daily routine.

Remedial programme

Assistive Devices

Assistive technology is a device or service that helps a person with a disability in his or her daily activities. Assistive technology can be found in the home, workplace, school, and community. Assistive technology helps a person with a disability to become or remain independent.

Abacus, rulers, geometric solids, counters, measuring cup, Rubik cube, play money, Skillofun construction clock and Skillofun number and beads sets were used. E-manipulative, virtual manipulative, illuminations resources for teaching mathematics, electronics worksheets and math software games were used.
Researcher developed three computer programs for assessment of students, namely Money, Time and Metric system.

Procedure of data collection
On the basis of above tests all the identified cases were assigned to two groups, one experimental group and one control group. Treatments were allotted randomly to all two groups. Self-made tests called Tool on Adaptive Reasoning; on Procedural Fluency and on Connections of mathematics with other subjects were used to assess adaptive reasoning, procedural Fluency and Connections of mathematics with other subjects. These three measures served as pre-test and are dependent variables.
In the next phase, intervention was provided to subjects in treatment group through assistive devices in the form of remediation. 45 sessions each of 40 minutes duration were conducted in groups. Control group was taught by traditional chalk and talk method. Control group received treatment for same duration and on same content matter.
Last phase consisted of re-administration of tests to assess Adaptive reasoning, Procedural fluency & Connections of mathematics with other subjects in order to see the effectiveness of assistive devices. This provided scores of post-test.

Results
Effectiveness of Assistive devices on Adaptive Reasoning
The t-values for adaptive reasoning of assistive devices group at both pre-test and post-test level have been presented below in Table 1.

Table 1. t-test for correlated means for adaptive reasoning

Adaptive Reasoning	N	Mean	Std. Deviation	Std. Error Mean	t-value	r value	p-value
Pre-test	14	9.86	1.41	0.38	28.71	0.32	.0001**
Post-test	14	25.29	1.82	0.49			

Table values of t at 0.05 = 2.056; 0.01 = 2.779; for df = 26

As shown in table 1, the scores of Experimental group are represented for adaptive reasoning variable at both pre-test and post-test level. The difference between pre-test and post-test means of adaptive reasoning is 14.93 for assistive devices group. This difference was found to be significant (t_{26} = 27.71 at 0.01 level). This indicates that subjects performed better after administration of assistive devices in adaptive reasoning ability at post-test level.
The t-values for adaptive reasoning of assistive devices group and control group at post-test level have been presented below in Table 2.

Table 2. t-test for independent means for adaptive reasoning in assistive devices group and control group

Groups	N	Mean	Difference in mean	SD	Value of t-ratio	p-value
Assistive devices	14	25.29	13.22	1.82	17.64	0.0001**
Control group	15	12.07		2.19		

Table values of t at 0.05 = 2.052; 0.01 = 2.771; for df = 27

As shown in the table 2 the subjects in experimental group had higher mean scores in the variable of mathematical skill of adaptive reasoning at post-test level than control group which received traditional chalk and talk in adaptive reasoning. There was a difference of 13.22 between the two

groups which was found to be significant (t_{27} = 17.64; p < 0.01). This indicates that experimental group had better adaptive reasoning ability in mathematics than control group at post-test level.
Above finding related to experimental group have been supported by other studies (Lokken, 2012; Bressette, 2010; & Lack, 2010) indicated that intensive reasoning strategies are needed to strengthen mathematical reasoning. All these studies did not focus on adaptive reasoning specifically, but one can conclude from these studies that reasoning skills of children can be enhanced with the help of some reasoning strategies and that will make a significant difference in the performance.
The above results suggest that the activities of assistive devices e.g. concrete material like abacus, rulers, geometric solids, counters, measuring cup, Rubik cube, play money, construction clock and beads sets and manipulatives e.g. E-manipulative, virtual manipulative, illuminations resources for teaching mathematics, electronics worksheets and math software games develop adaptive reasoning of the subjects. Based on above findings, therefore hypothesis (1) that the children with dyscalculia will improve significantly in adaptive reasoning after administration of assistive devices technique of intervention is accepted. Also, the objective of studying the effect of assistive devices on adaptive reasoning of fourth graders with dyscalculia has been fulfilled.

Effectiveness of Assistive devices on Procedural Fluency
The t-values for procedural fluency of assistive devices group at both pre-test and post-test level have been presented below in Table 3.

Table 3. t-test for correlated means of procedural fluency

Procedural Fluency	N	Mean	Std. Deviation	Std. Error Mean	t-value	r value	p-value
Pre-test	14	8.29	2.43	0.65	9.84	0.29	.0001**
Post-test	14	17.14	3.16	0.85			

Table values of t at 0.05 = 2.056; 0.01 = 2.779; for df = 26

As shown in table 3, the scores of experimental group are represented for procedural fluency variable at both pre-test and post-test level. The difference between pre-test and post-test means of procedural fluency is 8.86 for assistive devices experimental group. This difference was found to be significant (t_{26} = 9.84 at 0.01 level). This indicates that subjects performed better after administration of assistive devices in procedural fluency ability at post-test level.
The t-values for procedural fluency of assistive devices group and control group at post-test level have been presented below in Table 4.

Table 4. t-test for independent means for procedural fluency in assistive devices group and control group

Groups	N	Mean	Difference in mean	SD	Value of t- ratio	p-value
Assistive devices	14	17.14	5.48	3.16	5.54	0.0001**
Control group	15	11.67		2.09		

Table values of t at 0.05 = 2.052; 0.01 = 2.771; for df = 27

As shown in the table 4 the subjects in experimental group had higher mean scores in the variable of mathematical skill of procedural fluency at post-test level than control group which received traditional chalk and talk in procedural fluency. There was a difference of 5.48 between the two groups which was found to be significant (t_{27} = 5.54; p < 0.01). This indicates that experimental group had better procedural fluency ability in mathematics than control group at post-test level.
Above finding related to experimental group have been supported by other studies by (Bautista, 2013; Foster, 2013; Tseng, 2012; Kridler, 2012; Khairani and Nordin, 2011; Samuelsson, 2010; & Wu, 2008) indicate that procedural fluency is a significant strand in the mathematics. All of them

did not focus on procedural fluency, but one can conclude from above studies that teachers should make balance between procedural fluency and other skills of mathematics. Procedural fluency can be taught by assistive devices with a balanced approach.
The above results suggest that the activities of assistive devices e.g. concrete material, manipulatives and math software games develop procedural fluency of the subjects. Based on above findings, therefore hypothesis (2) that the children with dyscalculia will improve significantly in procedural fluency after administration of assistive devices technique of intervention is accepted. Also, the objective of studying the effect of assistive devices on procedural fluency of fourth graders with dyscalculia has been fulfilled.

Effectiveness of Assistive devices on Connection of mathematics with other subjects
The t-values for connections of mathematics with other subjects of assistive devices group at both pre-test and post-test level have been presented below in Table 5.

Table 5. t-test for correlated means for connection of mathematics with other subjects

Connections of mathematics with other subjects	N	Mean	Std. Deviation	Std. Error Mean	t-value	r value	p-value
Pre-test	14	11.29	1.68	0.45	31.46	0.24	.0001**
Post-test	14	27.64	2.59	0.69			

Table values of t at 0.05 = 2.056; 0.01 = 2.779; for df = 26

As shown in table 5, the scores of experimental group are represented for connections of mathematics with other subjects' variable at both pre-test and post-test level. The difference between pre-test and post-test means of connections of mathematics with other subjects is 16.36 for Experimental group i.e. assistive devices group. This difference was found to be significant (t_{26} = 31.46 at 0.01 level). This indicates that subjects performed better after administration of assistive devices in connections of mathematics with other subjects at post-test level.
The t-values for connections of mathematics with other subjects of assistive devices group and control group at post-test level have been presented below in Table 6.

Table 6. t- test for independent means for connections of mathematics with other subjects in assistive devices group and control group

Groups	N	Mean	Difference in mean	SD	Value of t- ratio	p-value
Assistive devices	14	27.64	15.18	2.59	19.79	0.0001**
Control group	15	12.47		1.41		

Table values of t at 0.05 = 2.052; 0.01 = 2.771; for df = 27

As shown in the table 6 the subjects in experimental group had higher mean scores in the variable of mathematical skill of connections of mathematics with other subjects at post-test level than control group which received traditional chalk and talk in connections of mathematics with other subjects. There was a difference of 15.18 between the two groups which was found to be significant (t_{27} = 19.79; $p < 0.01$). This indicates that experimental group had better understanding of connections of mathematics with other subjects in mathematics than control group at post-test level.
Above finding related to experimental group have been supported by other studies (Omaha and Nebraska, 2011; Mwakapenda and Dhlamini, 2010; Kailikole, 2009; Wilburne and Napoli, 2008; Furner and Kumar, 2007; Michelsen, 2006; & Quan, 2006) indicate that assistive devices play a vital role in making connections of mathematics with other subjects and facilitate learning of language, science and arts. Teacher education programs can benefit from the given replications.

Connections of mathematics with other subjects have improved significantly by usage of assistive devices.

The above results suggest that the activities of assistive devices e.g. concrete material, manipulatives and math software games develop connections of mathematics with other subjects of the subjects. Based on above findings, therefore hypothesis (3) that the children with dyscalculia will improve significantly in making connections of mathematics with other subjects after administration of assistive devices technique of intervention is accepted. Also, the objective of studying the effect of assistive devices on connections of mathematics with other subjects of fourth graders with dyscalculia has been fulfilled.

Assistive devices have been useful in enhancing adaptive reasoning, procedural fluency and connections of mathematics with other subjects as mathematics skills. Many other studies (Tucker and Johnson, 2017; Long, 2015; Russell, 2014; Mishra, 2014; Luckwell, 2014; Yakubova and Bouck, 2014; Amaker, 2014; Amiripour, Bijanzadeh, Rostamy-Malkhalifeh and Najafi, 2012; Seo and Bryant, 2012; Westenskow, 2012; Amiripour, Mohammad, Bijan-zadeh, Pezeshki and Najafi, 2011; Nugent, 2010; Guevara, 2009; Wilson, Dehaene, Pinel, Revkin, Cohen and Cohen, 2006; Wilson, Revkin, Cohen and Dehaene, 2006; & Suh, 2005) also point to similar findings.

Discussion

Students with dyscalculia struggle with a rapid pacing of introducing new mathematics concepts, and insufficient examples, explanations, practice, and review in general education classrooms. In fact, teachers are willing to provide additional instructional and adapted materials to facilitate the successful learning of students with dyscalculia in their classrooms. The present study is based on the assumption that problems of dyscalculic children can be remediated by suitable measures and various effective intervention strategies. As the quality and availability of technology has dramatically increased in the past decade, researchers and educators have made efforts to apply technology to the mathematics curriculum for students with dyscalculia to enhance their mathematics performance.

In the present study, assistive devices have been found to be useful in developing adaptive reasoning, procedural fluency and connections of mathematics with other subjects among children with dyscalculia as evidenced by a) gain scores in pre to post-test stage b) difference in experimental and control group at post-test.

The findings also provide a platform for the dyscalculic children to adopt latest technology and develop thinking styles. Overall, intervention strategies are beneficial for the learners in the classroom.

In the present research, assistive technology devices has a significant effect on the performance of students having difficulty in the area of attention regulation, academic achievement and numerical ability, positive and negative experiences in mathematics, computation and increasing ability of mathematical word problem-solving, fraction learning, logical thinking, explanation, reflection, justification, ability to relate diverse mathematical concepts. Teachers can adapt assistive devices according to the needs of students.

Assistive devices include technology solutions for making decisions about specific requirements of students. After modification or customization, the devices can be used to meet the individual needs of students. These devices are useful to improve physical disability as well as intellectual functioning. Low tech tools for example concrete devices while high tech tools like software games can be used to develop cognition among students.

Based on the results obtained in the present study, it is shown that the t-ratio in all the three mathematical skills that shows it doesn't benefit all the mathematical skills equally well. This could be due to complexity of mathematical skills. Adaptive reasoning refers to the capacity to think logically about the relationships among concepts and situations and to justify and ultimately prove the correctness of a mathematical procedure or assertion. Adaptive reasoning also includes reasoning based on pattern, analogy or metaphor (Wikipedia, 2013). Secondly Kilpatrick,

Swafford and Findell (2001) and Watson and Sullivan (2008) defined procedural fluency as including skill in carrying out procedures flexibly, accurately, efficiently, and appropriately, and, in addition to these procedures, having factual knowledge and concepts that come to mind readily. Third mathematical skill i.e. connections in mathematics can be found within a mathematical topic, across strands and process standards, and outside mathematics, such as connections to other subjects or real-world contexts. Connections make mathematics more meaningful and make learning easier. Recognizing and establishing connections can greatly assist students in their efforts to problem-solve, reason, and communicate about mathematics (Annenberg Learner, 2015). Thus, every experimental treatment affects mathematical skills differently due to their specific characteristics.

With large number of students identified with dyscalculia in schools across India, it is only appropriate to determine if teachers are adequately prepared to make learning and performance effective and efficient for this special population of students. Teachers need to have adequate knowledge of the cognitive, social and behavioural characteristics of students with dyscalculia, so that they are able to design instructional models that work for these students. Knowledge of dyscalculia among teachers is also needed for another reason, in order for professionals to avoid stereotypical description of individuals with dyscalculia, because the success of inclusive classrooms is related to teachers' knowledge of the unique needs of their students.

In conclusion, the intervention strategy of assistive devices is beneficial in improving all mathematical skills viz. adaptive reasoning, procedural fluency and connections of mathematics with other subjects of children with dyscalculia of experimental group. Subjects showed significant improvement from pre-test scores to post test scores in all the three dependent variables. The subjects in Experimental group were significantly better than Control group on all three dependent variables.

References

1. Amaker, H. T. (2014). *The impact of educational technology, interactive whiteboard, on elementary education self-contained special education student performance in English language arts and mathematics in a rural district in South Carolina.* Ph.D. Thesis, South Carolina: Orangeburg.
2. Amiripour, P., Bijan-zadeh, M. H., Pezeshki, P., & Najafi, M. (2011). Effects of assistive technology instruction on increasing motivation and capacity of mathematical problem solving in dyscalculia students. *Educational Research*, *2* (10), 1611-1618.
3. Amiripour, P., Bijanzadeh, M. H., Rostamy-Malkhalifeh, M., & Najafi, M. (2012). The effects of assistive technology on increasing capacity of mathematical problem solving in dyscalculia students. *Journal of Applied Mathematics*, *8* (31), 47-55.
4. Annenberg learner (2015). *Connections.* Retrieved April 14, 2013 from https://learner.org/courses/teachingmath/grades3_5/session_06/index.html
5. Annenberg learner (2015*). Learning math, a series of five online multimedia-based courses in the NCTM content standards.* Retrieved July 17, 2015 from www.learner.org/courses/learningmath/.
6. Badian, N. A. (1983). *Mathematical and nonverbal learning*. New York: Grune and Stratton.
7. Bautista, R. G. (2013). The students' procedural fluency and written-mathematical explanation on constructed response tasks in physics. *Journal of Technology and Science Education*, *3* (1), 68-89.
8. Beygi, A., Padakannaya, P., & Gowramma, I. P. (2010). A remedial intervention for addition and subtraction in children with dyscalculia. *Journal of the Indian Academy of Applied Psychology*, *36* (1), 9-17.
9. Bressette, S. J. (2010). *A comparison of fourth grade students with learning disabilities and their nondisabled peers on mathematics reasoning performance.* Unpublished Doctoral

Thesis, Minnesota: Walden University. Retrieved August 13, 2013 from http://search.proquest.com/docview/820649447?accountid=28367. (820649447).
10. Chauhan, D. (2004). *The effectiveness of different strategies for remediating dyscalculia in primary school children.* Unpublished doctoral thesis, Chandigarh: Panjab University.
11. Foster, C. (2013). Mathematical études: Embedding opportunities for developing procedural fluency within rich mathematical contexts. *International Journal of Mathematical Education in Science and Technology, 44* (5), 765-774.
12. Furner, J. M., & Kumar, D. D. (2007). The mathematics and science integration argument: A stand for teacher education. *Eurasia Journal of Mathematics, Science & Technology Education, 3* (3), 185-189.
13. Geary, D. C. (2006). *Dyscalculia at an early age: Characteristics and potential influence on socio-emotional development.* Retrieved February 12, 2013 from http://web.missouri.edu/~gearyd/files/GearyANGxp.pdf
14. Gowramma, I. P. (2000). Development of remedial instruction programme for children with dyscalculia in primary school. Unpublished doctoral thesis. India: University of Mysore.
15. Guevara, F. D. (2009). *Assistive technology as a cognitive developmental tool for students with learning disabilities using 2D and 3D computer objects.* Unpublished Doctoral Thesis, El Paso: The University of Texas. Retrieved July 12, 2013 from http://search.proquest.com/docview/305062619?accountid=28367. (305062619).
16. Guillemot, T. (2010). *Dyscalculia – An overview of research on learning disability*. Retrieved September 10, 2013 from http://www.idt.mdh.se/kurser/ct3 340/ht09/ADMINISTRATION/IRCSE09-submissions/ircse09_submission_25.pdf
17. Jha, S. K. (2012). Mathematics performance of primary school students in Assam (India): An analysis using Newman procedure. *International Journal of Computer Applications in Engineering Sciences, 2* (1), 17-21.
18. Kailikole, K. L. (2009). *Meaning making in a college mathematics lecture format: The intersection of mathematics, language, and cultural meaning systems (Electronic Theses and Dissertations)*. San Diego: University of California.
19. Khairani, A. J., & Nordin, M. S. (2011). The development and construct validation of the mathematics proficiency test for 14-year-old students. *Asia Pacific Journal of Educators and Education, 26* (1), 33–50.
20. Kilpatrick, J., Swafford, J. & Findell, B. (2001). *Adding it up: Helping children learn mathematics.* Washington: National Academy Press.
21. Kosc, L. (1974). Developmental dyscalculia. *Journal of Learning Disabilities, 7* (4), 46–59.
22. Koumoula, A., Tsironi, V., Stamouli, V., Bardani, I., Siapati, S., & Graham, A. (2004). An epidemiological study of number processing and mental calculation in greek school children. *Journal of Learning Disability, 37* (5), 377-88.
23. Kridler, P. G. (2012). *Procedural and conceptual knowledge: A balanced approach?* Unpublished Doctoral Thesis, Fairfax VA: George Mason University. Retrieved Feburary 11, 2013 from http://search.proquest.com/docview/304764388?account id=28367(304764388).
24. Lack, B. (2010). *Student participation in mathematics discourse in a standards-based middle grades classroom.* Unpublished Doctoral Thesis, Atlanta USA: Georgia State University. Retrieved July 12, 2013 from http://search.proquest.com/docvie w/859014511? accountid=28367. (859014511).
25. Lewis, C., Hitch, G. J., & Walker, P. (1994). The prevalence of specific mathematical difficulties and specific reading difficulties in 9 to 10 year old boys and girls. *Journal of Child Psychology and Psychiatry, 35* (2), 283-92.
26. Lokken, L. J. (2012). *Impact of teaching reasoning strategies on math fact fluency and problem-solving skills.* Unpublished Doctoral Thesis, Southwest: Minnesota State University. Retrieved July 17, 2013 from http://search.proquest.com/ docview/321198149? accountid=28367. (321198149).

27. Long, K. T. (2015). *Increasing number sense in special needs students using assistive technologies.* Unpublished Doctoral Thesis, Minnesota: Capella University. ProQuest Dissertations & Theses A&I. Retrieved March 16, 2016 from http://search.proquest.com/docview/17319 40739?accountid=28367
28. Luckwell, C. (2014). Maximizing student experience in mathematics: Traditional tools versus digital technologies. *Mount Royal Undergraduate Education Review, 1* (1), 1-16.
29. Michelsen, C. (2006). Functions: A modelling tool in mathematics and science. *Analyses, 38* (3), 269-280.
30. Mishra, K. (2014). *Effect of low tech tools for inclusive education in mathematics on attention regulation, academic achievement and numerical ability among the dyscalculic students of primary classes.* Ph.D. Thesis, Agra: Dayalbagh Educational Institute.
31. Mwakapenda, W., & Dhlamini, J. (2010). Mathematics and other learning areas: Emerging tensions from a study involving four classroom teachers. *Pythagoras, 71*, 22-29. Retrieved September 15, 2013 from www.pythagoras.org.za/index.php/pdf
32. Nugent, B. F. (2010). *The impact of use of mathematics manipulatives on attitudes toward mathematics success among students in a multigrade classroom.* Unpublished Doctoral Thesis, Minnesota: Walden University. *ProQuest Dissertations and Theses,* 203. Retrieved July 17, 2013 http://search.proquest.com/docview/820588786?a ccountid=28367. (820588786).
33. Omaha, K. G., & Nebraska (2011). *A study of mathematical connections through children's literature in a fifth- and sixth-grade classroom.* Retrieved September 9, 2013 from http://scimath.unl.edu/MIM/files/research/Glacey_AR_final_LA.pdf
34. Quan, C. T. (2006). *Arts at the heart: Making connections with at-risk middle school students.* Unpublished Doctoral Thesis, California US: University of La Verne. Retrieved July 17, 2013 from http://search.proquest.com/docview/304959184?accountid=28367. (304959184).
35. Ramaa, S. (1990). *Arithmetic diagnostic test for primary school children, study of neuropsychological process and logico-mathematical structure among different types of dyscalculics.* Mysore: NCERT, Regional College of education. Retrieved July 17, 2013 from http://www.nimindia.org/grade%20%level%20pdf
36. Ramaa, S., & Gowramma, I. P. (2002). A systematic procedure for identifying and classifying children with dyscalculia among primary school children in India. *Dyslexia, 8* (2), 67-85.
37. Raven, J., Raven, J. C., & Court, J. H. (1998). *Manual for raven's progressive matrices and vocabulary scales, section 1: General overview*. San Antonio, TX: Harcourt Assessment. Retrieved November 25, 2013 from http://www.cc.gatech.edu/~bmcgregg/AddressingRavens.pdf.
38. Rozario, M., & Kapur, M. (1992). Intervention strategies for students with problems in learning arithmetic. *Perspective in Education, 8*, 205-210. Retrieved September 4, 2013 from http://www.jiacam.org/040/SLD.pdf
39. Russell, R. (2014). *The impact of using calculators as an accommodation on the math achievement of students with learning disabilities.* Unpublished Doctoral Thesis, United States: Grand Canyon University. ProQuest Dissertations & Theses A&I. Retrieved March 16, 2016 from http://search.proquest.com/docview/1564022570?accountid=28367
40. Samuelsson, J. (2010). The impact of teaching approaches on students' mathematical proficiency in Sweden. *International Electronic Journal of Mathematics Education, 5* (2). Retrieved September 9, 2013 from https://www.iejme.com/022010/full.pdf
41. Seo, Y. J., & Bryant, D. (2012). The multimedia CAI program for students with mathematics difficulties. *Remedial and Special Education, 33* (4), 217-225.
42. Shalev, R. S., & Gross-Tsur, V. (2001). Developmental dyscalculia. *Pediatrician Neurological, 24* (5), 337-42.
43. Shih, M. (2005). *Effects of number sense intervention on second-grade students with mathematics learning disabilities.* Unpublished Doctoral Thesis, Austin: The University of

Texas. Retrieved September 16, 2013 from http://search.proquest.com/docview/908644522?accountid=3217170 (908644522).
44. Suh, J. M. (2005). *Third graders' mathematics achievement and representation preference using virtual and physical manipulatives for adding fractions and balancing equation.* Fairfax Virginia: Georgia Mason University.
45. Tseng, D. H. (2012). Conceptual and procedural knowledge in mathematics education in the case of law of exponents. *Polygon Spring*, 5-7. Retrieved September 9, 2013 from http://www.mdc.edu/hialeah/polygon/DTseng.pdf
46. Tucker, S. I., & Johnson, T. N. (2017). I thought this was a study on math games: Attribute modification in children's interactions with mathematics apps. *Education Science, 7*, 1-20. Retrieved December 15, 2017 from www.mdpi.com/journal/education
47. Watson, A., & Sullivan, P. (2008). Teachers learning about tasks and lessons. In D. Tirosh & T. Wood (Eds.), *Tools and resources in mathematics teacher education* (pp. 109–135). Sense Publishers: Rotterdam.
48. Watson, A., & Sullivan, P. (2008). *Tools and resources in mathematics teacher education*. Rotterdam: Sense Publishers.
49. Westenskow, A. (2012). *Equivalent fraction learning trajectories for students with mathematical learning difficulties when using manipulatives*. Unpublished Doctoral Thesis, Logan: Utah State University. Retrieved September 16, 2013 from http://search.proquest.com/docview/1251433825?accountid=28367. (1251433825).
50. Wikipedia (2013). *Adaptive reasoning.* Retrieved September 22, 2013 from http://en.wikipedia.org/wiki/Adaptive_reasoning
51. Wilburne, J. M., & Napoli, M. (2008). Connecting mathematics and literature: Analysis of pre-service elementary school teachers' changing beliefs and knowledge. *Issues in the Undergraduate Mathematics Preparation of School Teachers, 2* (Pedagogy), 1-10.
52. Wilson, A. J., Revkin, S. K., Cohen, D., Cohen, L., & Dehaene, S. (2005). An open trial assessment of "The Number Race", an adaptive computer game for remediation of dyscalculia. *Behavioral and Brain Functions*. Retrieved September 17, 2013 from http://www.behavioralandbrainfunctions.com/content/2/1/20
53. Wilson, A. J., Dehaene, S., Pinel, P., Revkin, S. K., Cohen, L., & Cohen, D. (2006). Principles underlying the design of "The Number Race", an adaptive computer game for remediation of dyscalculia. *Behavioral and Brain Functions*. Retrieved September 17, 2013 from http://www.behavioralandbrainfunctions.com/content/2/1/19
54. Wu, Z. (2008). Using the MSA model to assess Chinese sixth graders' mathematics proficiency. *Journal of Mathematics Education, 1* (1), 74-95.
55. Yakubova, G., & Bouck, E. C. (2014). Not all created equally: Exploring calculator use by students with mild intellectual disability. *Education and Training in Autism and Developmental Disabilities, 49* (1), 111–126.