Effects of Virtual Manipulative in enhancing Basic Arithmetic for Students with Developmental Dyscalculia

Dr.M.Prabavathy[1], Director, Centre for Differently Abled Persons, Bharathidasan University, Tamil Nadu, India,
R.Sivaranjani[2], Research Scholar, Centre for Differently Abled Persons, Bharathidasan University, Tamil Nadu.

ABSTRACT

Mathematics is the universal language, and also known as the Queen of science. At the basic level, it deals with the concept of numbers, sequence, functions, geometric shapes, place values and comparing quantities. These basic concepts are crucial for our daily living. This concept has to be built at the primary level of schooling. But, unfortunately, children with Developmental Dyscalculia who constitute around 3-6% face difficulty in the acquisition of basic primary level arithmetic skills. These children have difficulty learning and recalling basic number facts, poor understanding of the signs, trouble with understanding place value, sequencing, comprehending math language and phrases. The purpose of this present study was to analyze the efficacy of virtual manipulatives in enhancing basic arithmetic among primary school students with Dyscalculia. In the present study, the researcher explores the efficacy of virtual manipulative in enhancing Basic Arithmetic of children with developmental Dyscalculia. The current investigation was carried out with 32 students with symptoms of Dyscalculia in a rural district of Tamilnadu. The purposive sampling design was adopted. Virtual manipulatives involving various learning modalities was designed based on the diagnostic test. The intervention was given for two months. The findings of the study showed that virtual manipulatives enhance the basic arithmetic skill of children with Dyscalculia and also enhance their motivation to learn Mathematics.

Keyword: Learning Disabilities, Math Learning Disabilities, Virtual Manipulative, Basic Arithmetic, Primary Level

Introduction

"I hear, and I forget. I see, and I remember. I do, and I understand."
-Confucius 551-479 BC.

Arithmetic learning disorders (developmental Dyscalculia) denote circumscribed and outstanding difficulties in the acquaintance of arithmetic skills. The term Dyscalculia refers to difficulties in learning or comprehending arithmetic. Dyscalculia is demonstrated by difficulty acquiring a sense of number, and problems arise from developmental issues associated with the acquisition of reverse dynamic cerebellar models (functioning below the consciously aware level) associated with the second stage of the basic physics (of number) of the child. Children with Dyscalculia exhibit difficulty in learning or comprehending basic arithmetic skills such as understanding number sequence understand how to manipulate numbers, and master arithmetic facts (Kaufmann et al. 2012 & Lander.et.al 2004). Dyscalculia is a learning disorder that involves difficulty in learning of mathematical concepts. The term dyscalculia comes from Greek and Latin, which means "Counting badly". The prefix "dys" comes from Greek means "badly" "calculia" comes from the Latin "calculare", which means "to count" the word "calculare" comes from "calculus" (Bweyhunle 2016). Importantly, Dyscalculia is not a unitary concept, and the associated cognitive profiles might vary widely between and within individuals (Kaufmann et al. 2006 & Wilson 2007).

The estimated prevalence of 3% to 7% of children is reported to have developmental Dyscalculia in India. *Dyscalculia* is often generally characterized by difficulty in learning or understanding basic mathematical operations. A child with the arithmetic disorder might have difficulty in organizing problems; follow multiple-step calculations such as division; transposing numbers accurately, such as turning 89 into 98; distinguishing right from left; and using mathematical calculation signs(Von, Shelv 2007). They are also confused about basic operations and facts that are easier for their peers (NASETLD 2017). It is widely agreed that Dyscalculia is a highly familial disorder - the risk for siblings of children suffering from Dyscalculia is five to ten times higher than in the general population (Shalev 2001). Through, developmental Dyscalculia may be present as a single-deficit disorder (e.g., core deficit of 'number sense') (Landerl 2004 & Wilson 2007), many affected children exhibit associated cognitive problems, both within and outside the numerical domain (Kaufmann 2005 & Shalev 2001). The frequent occurrence of co-morbidities coincides with recent findings reporting a substantial genetic overlap between various developmental learning disorders such as Dyscalculia, dyslexia and attention-deficit hyperactivity disorder (Plomin 2007), Hence, our current understanding of the behavioural manifestations and (neuro) cognitive foundations of developmental Dyscalculia remains incomplete. Recent studies have shown that childhood math anxiety is related to abnormal functional responses in brain regions and circuits that are crucial for the growth of negative emotions (Yong et al. 2012). This research article aims to exhibit the need to integrate technology in learning involving different learning modalities for children with or without disabilities. Moreover, the paper aims to illustrate how virtual manipulatives can foster educational understanding and enhance classroom instructions/interventions for students with developmental Dyscalculia.

Recent Thoughts on Numerical Cognition and Developmental Dyscalculia

Mathematical difficulties during early childhood also have adverse long-term consequences for career choice, employment, and professional success. Children can discriminate between different small numbers of items and can determine numerical equivalence across perceptual modalities (Wilson 2007&Von Aster 2007). This may indicate the possession of true numerical concepts; alternatively, purely perceptual discriminations may underlie these abilities.

Mathematicians all over the world have struggled to describe the ultimate rudiments of mathematics adequately. The great Nobel laureates Albert Einstein and Eugene Wigner were puzzled by this issue of mastery in math. Devlin's describes "Mathematics as the science of patterns includes the study of the patterns of shape, motion, number, and behaviour". Abundant imaging research has found in recent decades that the cerebellum is a master computational system for the cerebral cortex 'motor and cognitive areas. Within the framework of these findings and in the frame of reference of mathematics as model science, it is suggested that the cerebellum calculate pattern sequences that predict the future state of affairs in movement and thought. Rather, the cerebro-cerebellar approach brings new cognitive processes to bear that provide more detailed and comprehensive explanations both for initial learning of numbers and their manipulation, and the subsequent, ongoing optimization and increased complexity of neural patterns that make up both mathematics and sense of number. Based upon the previous cerebella learning and optimization of patterning in the conceptual primitives (the bases for symbol system), it is now argued that mathematics is a product of the computational mechanisms of the human cerebellum, and is the result of the cerebellum's distillation of the features objects moving in space. Hayter, Langdon and Ramani conducted imaging research on the involvement of the cerebellum in the arithmetic calculation in verbal working memory.

Technology Integration in Education

Due to the emergence of information and communication technologies, the instructional scenario has evolved profoundly. Concepts are essential for understanding mathematics and are also a source of frustration for students struggling with mathematics, many of whom find it hard to grasp even simple math concepts. The use of tangible objects also referred to as manipulatives, is a common approach to helping students understand abstract concepts. Manipulatives allow students and teachers to portray abstract math concepts in concrete terms. They also allow students to link these concepts to their prior knowledge.

In the past, most classrooms relied only on physical manipulatives. But today, most of the classrooms have improved access to computers and mobile learning. Virtual manipulatives are becoming more common tools of learning. Virtual manipulatives have emerged as effective tools for students and can help support them in learning to use tools for mathematics. Virtual manipulative improve the understanding of the abstract symbolic language of math for students who struggle in math and often find it hard to connect visual and symbolic representations.

In addition to that, virtual manipulatives can be altered in ways that real ones cannot. For example, the size, shape, and colour of a block can be changed that can capture the attention of students. In many cases, teachers create models using virtual versus physical objects. An added benefit of virtual manipulatives it enables students to learn at their learning modality. Free and available web-based applications offer opportunities for teachers and students to implement virtual manipulatives (i.e., visual model tools) during mathematics instruction. For example, using Illuminations (https: //illuminations.nctm. org/Games-Puzzles.aspx) or Conceptual Math (https: //www. conceptuamath.com), teachers can provide instruction in mathematics. These web-based applications offer various visual modality tools (e.g., pattern block, number line, vertical bar, dots) for each relevant concept (e.g., equivalent fractions, addition, subtraction, multiplication, division, word problems). Using interactive whiteboards, teachers can demonstrate how to connect virtual manipulative to each fraction concept. Besides, using iPod applications (e.g., ABCya.com's Virtual Manipulative, Braining camp's Dividing Fractions), teachers can assist individual students to explore fractions using their own mobile devices. Another feature of virtual manipulative tools in National Library of Virtual Manipulatives accessible at http://nlvm.usu.edu/en/nav/ vlibrary.html, Fun Fraction- http://funfraction.org and iPod applications of Conceptual Math's Student App and Braining camp's Dividing Fraction are inbuilt with the ability to monitor student progress of specific concepts and skills through the quizzes and games (Bouck & Flanagan, 2010; Edyburn, 2013). In this student-centered learning and evaluation environment, virtual-manipulative based evaluation provides remedial concepts after learning trials. Virtual manipulative is defined as "an immersive, web-based graphic illustration of a dynamic object that poses mathematical knowledge-building opportunities" (Moyer, 2002). This intervention should be able to teach children with Dyscalculia the basic arithmetic skill, addition and subtraction operation.

Literature review

Different studies have shown the benefits of using virtual instructional materials in educational settings through a variety of innovative teaching and learning activities. Dick indicates that virtual worlds allow learning experiences under the constructivist pedagogical approach, utilizing the interaction between avatars and the virtual environment. Dede discusses the advantages of developing activities that have no undesired repercussions or consequences in the real world, while knowledge is obtained by "learning by doing" in a secure way, with a sense of immersion in an environment similar to reality.

Moyer- Packenham and Westenskow (2013) conducted a meta-analysis of the use of virtual manipulatives. They analyzed 32 studies showing a moderate effect of virtual manipulations on math performance compared to typical general education classroom instruction (e.g. instruction with physical manipulations and abstract symbols of mathematics, but not the use of virtual manipulations as a tool). Recently, other researchers have investigated the effects of virtual manipulatives as a tool with students with Learning Disability using a single-subject research design.

Reneau (2012) and Shin (2013) investigated the effect of using virtual manipulatives to teach fraction concepts and skills within the context of word problem solving to students with Learning Disability. The results from these two experiments showed changes in word problem-solving ability during the intervention process as opposed to Output in the baseline setting, which included issues with fractions. Satsangi and Bouck (2015) found virtual manipulatives as an effective tool for teaching the concept of area and perimeter to students with Learning Disability.

Suh and Moyer (2008) indicated that the applet seemed to benefit special needs learners by giving them built-in supports for the mathematical ideas that reduced their cognitive overload" (p. 303). By using the computer-built-in graphic images and symbolic notations, users could be able to focus on the connections and relationship of mathematical concepts (Moyer-Packenham, Salkind & Bolyard, 2013; Suh & Moyer, 2008). Second, the application of virtual manipulative acts as individualized accommodations for students with Learning and mathematics difficulties (D. P. Bryant and B. R. Bryant, 2011; Edyburn, 2013). Virtual manipulatives help students to control the learning process by adjusting their own pace and repeating the practice, if necessary (Claes, Van Hove, Vandevelde, van Loon, & Schalock, 2012). Third, the use of virtual manipulative tools allows students to actively engage in their learning (Satsangi & Bouck, 2015). Recent studies have demonstrated that virtual manipulative encourage active engagement of students with Learning Disabilities and increase their academic achievement in fraction concepts and skills (Reneau, 2012; Shin, 2013). Fourth, many virtual manipulative websites are available free of charge and allow easy access to everyone (Bouck & Flanagan, 2010). Teachers with busy class schedules can access these ready-to-use online resources efficiently. Teachers do not need to clean up and store manipulative after using the visuals. Thus, their time can be better devoted to planning and implementing instruction for their students with Learning Disabilities, in responding to the needs of "web natives" who are adept at accessing and manipulating technology devices (Brown, 2013, p. 55), virtual manipulatives provide a variety of classroom opportunities.

According to Mazeyanti Mohd Ariffin., et al. (2017), Dyscalculia is one of the learning disability that directed to the number and math which can affect their math learning. Therefore, Dyscalculia children need an interesting and appropriate method in teaching math effectively, such as supportive learning tools. Dyscalculia children should use concrete models is the first step in building the meaning behind mathematical concepts. These models include a variety of math manipulatives, that students can handle during a lesson (Nagavalli, T., & Juliet, P.2015) understand mathematical ideas and better apply these ideas to life situations. Dyscalculia children are special need children that have different learning style compared to the normal children (Abd Halim et al. 2018) multisensory approach is one of the teaching strategies for Dyscalculia children. The multisensory learning involved auditory, visual, tactile and kinesthetic.

Kumar, S. Praveen & Raja, B.W.D. (2009) has shown that for the learning of mathematics concepts; visual perception, memory and logical thinking are the important prerequisites foundational skills. These fundamental skills have to be mastered, utilizing adequate training and practice. Visual perception and visual memory are important mathematical skills to master visual-spatial relationships. To be competent in acquiring mathematical skills, the child needs to visualize numbers and mathematical situations.

Annita W.; Nipper, Kelli L.and Nash, Linda E(2011) in the paper "Virtual vs. Concrete Manipulatives in Mathematics Teacher Education" presented the results of a three-year study in which seventy-eight middle grade teacher candidates used various concrete and virtual manipulatives to study fractions, integers and non-decimal-based numbers.

O'Dell, Jenna R.; Barrett (2017) in "Using a Virtual Manipulative Environment to Support Students' Organizational Structuring of Volume Units" investigated on Grade 3 and 4 students' organizational structure for volume units developed through repeated experiences with a virtual manipulative. The data consist of taped clinical interviews within a micro-genetic experiment. Student's strategy development using a virtual manipulative for counting cubes as a measure of prism volume was analyzed. The research showed that students could establish the concept of volume structure and advance their thought along a learning pathway for volume measurement through virtual manipulation.

Need and Significance of the Study

Children with mathematical learning disabilities have difficulty in attempting to solve simple math concepts and find it hard to recall and maintain basic mathematical facts and to work out their understanding and abilities to solve issues. If basic mathematical skills are not mastered, it may be difficult for learners to make advanced mathematical applications. Dyscalculia is seen as both a developmental and an acquired learning disability, and the effects of the disorder can be controlled at home and in school with appropriate support, guidance and interventions.

Statement of the Problem

This study is an attempt to screen the symptoms of Dyscalculia among primary school children. Based on diagnosis and difficulties, a virtual manipulative based intervention strategy for basic mathematics was adopted and experimented with the students. Thus the statement of the study was stated as "Effects of Manipulative in Teaching Basic Arithmetic to Students with Dyscalculia."

Objectives of the Study

The objectives give the right direction to the investigator and to be more appropriate. Following are the objectives of this study.

- To identify mathematics learning disabilities among IV standard students.
- To examine the performance in mathematics among IV standard students in Output as number concept, Sequential number difficulty, recognition of shapes, variation in arithmetic symbols and place value difficulties.
- To design virtual manipulative is to teach above-said concepts using digit modalities.
- To find the impact of the remedial measures and interventions for students with Dyscalculia is to improve mathematics.
- To study mathematics using virtual manipulative.
- To find out the effectiveness of virtual manipulative enhancing the mathematical skill among primary children.

Hypothesis

Virtual manipulative based intervention strategy will enhance the basic functional arithmetic learning of primary students with Dyscalculia.

Materials and methods

In this proposed study, single group pre-test& post-test experimental designs with virtual manipulative based Intervention Strategy as the independent variable and Mathematical skills as the dependable variable was adopted. A detailed case study of every child was also taken for analysis.

The population of the sample constitutes primary level students with Dyscalculia. The sample of this study is children with symptoms of Dyscalculia studying in primary schools in Tamil Nadu. In this study, the researcher planned to choose the sample from students studying in primary schools in and around Tiruchirappalli. As the sample is children with Dyscalculia, the purposive sampling method was adopted. The sample was selected based on the diagnosis done by the researcher and from anecdotal records of the child.

Research Tools and Analysis of Data

The following research tools are proposed to be employed for data collection:

1. Nagavalli Scale to Assess Dyscalculia (2015)
2. Observation schedules
3. Achievement Test for assessing the mathematics skills of students.

The data are collected through the administration of the above tools subjected to appropriate descriptive, differential, and non-parametric tests.

Phase I

An informal interview conducted with teachers working in and around Tiruchirappalli brought to light the fact that many students in primary schools face difficulty in acquisition of basic arithmetic skills.

Phase II

The students who had difficulty in basic arithmetic concepts were diagnosed using Nagavalli Scale to Assess Dyscalculia (2015). Based on the diagnoses, ten students studying in primary schools were selected as a sample. Children with Dyscalculia were identified through teacher's observation schedule, interview with parents and observation schedule for use by the researcher herself. Triangulation was done, and children who had difficulties in more than 60% of the dimensions were selected for the study.

Phase III

The pre-test scores and observation showed that Students had difficulty in math-related abilities of basic number identification, sequence, concepts of addition, subtraction, multiplication and division, number facts memorization of basic addition facts such as 2 + 4 instead of having to count by fingers, two or three-digit addition with regrouping; functional math applications of money and time concept; and verbal problem-solving ability (e.g., solving word problems). Some children have difficulties that revolve primarily around the automatic recall of facts, coupled with good conceptual abilities in mathematics, difficulties with computational algorithms, visual-spatial difficulties, such as difficulty lining up columns or with learning spatial aspects of math, such as geometry and number sequence awareness was deficient.

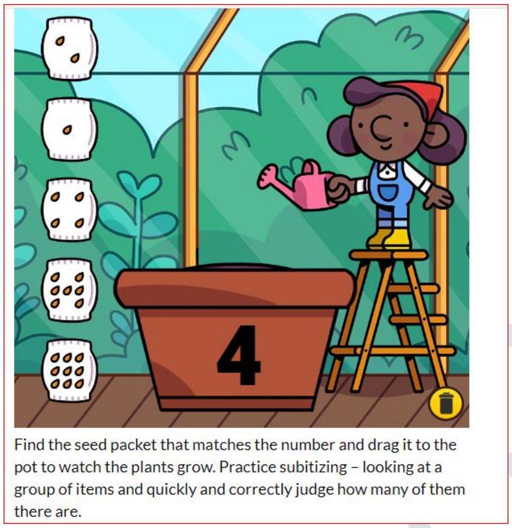
PHASE IV

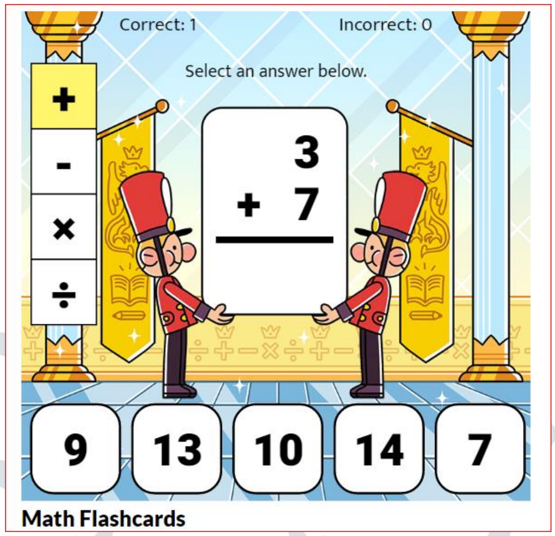
Virtual manipulative based activities relating to components of basic arithmetic of number identification, sequence, automatic recall of number facts was selected and evaluated. These activities were given to experts for validation.

A pilot study on 6 children studying in special schools was done for field try -out of the activities. Before the implementation of Intervention Strategies, a validated diagnostic test of basic arithmetic's was administered. The scores obtained were considered as those for the pre-test.

Phase V

Selection of Virtual manipulative based Intervention strategy: The performance of the children in the pre-test/diagnostic test was analyzed. The analysis revealed the difficulties faced by the children. Accordingly, the intervention programme was planned, keeping in mind the objectives to enhance the children's performance in basic arithmetic abilities. The intervention strategy was selected and made comprehensive and highly enriched with multisensory activities. The intervention programme using virtual manipulative using https://toytheater.com/ was implemented for two months for two hours a day.Number identification, number sequence, time and money concept, addition, subtraction, multiplication, division and angle were taught to the students through games.





Use of virtual manipulative using multisensory modalities ignited the interest of the students to learn and relearn the concepts with ease and remediation.

Phase VI

Post-test of basic arithmetic's was administered after two months of intervention.

Findings and Analysis of Data

Qualitative and quantitative data was collected. The scores were collected from single group students.

Table-1

Mean Standard deviation and t-value of the Pretest and Posttest scores of number basic arithmetic ability

Test	N	Mean	S.D	't' value	Remark
Pre	32	19.09	5.75	12.39	Significant at 0.01 level
Post	32	54.69	17.46		

It is concluded from the following table that the difference in performance between pre-test and post-test is significant at the 0.01 level. Thus virtual manipulatives based intervention strategy has enhanced the basic arithmetic ability of students with Dyscalculia.

Table: 2

Effect size (d) of the difference between the mean of the sample with Pretest and Posttest scores of basic arithmetic ability

Test	N	Mean	S.D	Effect size d
Pre	32	19.09	5.75	1.54
Post	32	54.69	17.46	

The findings of the above table, according to Cohen for interpreting d=0.8 or more shows large effect size, i.e. the differences are perceived. The findings show that the virtual manipulatives based intervention strategy has enhanced the basic arithmetic ability of children with Dyscalculia.

Qualitative Description of Student's Responses to Activities/Techniques

The findings of the case study showed that the use of virtual manipulatives as an instructional method to teach basic mathematics enabled the students to;

- Involve themselves with more enthusiasm in the learning activities.
- Enhanced self-esteem
- A gain in learning aspects.
- Readiness to comprehend and learn along with other children.
- Improvement in the ability to form an automatic association between numbers and images.

- Develop self-learning strategies in other subjects as well.
- Interest in doing school work.
- Joyful learning
- A paradigm shift of conscious incompetence to conscious competence.
- Enhanced Capability to master the new skill and unconsciously perform the mathematical task easily.

Discussion

The findings of the above study reiterate those of the researches done by other investigators. Teachers can scaffold instruction by applying virtual manipulatives in the extension of the previously taught concepts (B. R. Bryant et al., 2016; Leh & Jitendra, 2012). Instead of using all of the multimedia options provided by virtual manipulatives websites and applications, teachers can carefully select mathematical inputs and symbols from the multiple options to incorporate as a means for intensifying instruction (Mayer & Moreno, 2003). When using virtual manipulatives, teachers must check students' ability to use virtual manipulatives to accurately connect their visual models to mathematics concepts (McMahon & Walker, 2014). During this learning process, students should be encouraged to verbalize their mathematical thinking and justify their representations of problem situations (Hunt, 2014). Teachers should monitor students' actions of linking two dynamic visual models on the screen or touchpad by asking reflective questions such as these: "What does the virtual image represent in the given situation? What happened when you give a wrong answer? How can we define the mathematical relationship between the two virtual area models on the screen?" (Hunt, 2014; Moyer-Packenham & Westenskow, 2013). Teachers must employ thoughtful selection criteria to choose from a vast array of visual models offered on websites and as applications. Much like software, there is a need to consider instructional design features, particularly as they relate to the instructional needs of students with LD.

Implications

The outcome of this proposed study has shown that virtual manipulatives help children with Dyscalculia to acquire age-appropriate basic mathematical skills. The virtual manipulatives enable children with Dyscalculia to acquire and accomplish the skill of basic mathematical operations.

Conclusion

By promoting an interactive learning environment, teachers can help students with LD engage in their learning of mathematics. The use of virtual manipulatives is a viable tool for teaching basic arithmetic concepts and skills to students with Dyscalculia. Virtual manipulatives can be integrated into teacher-delivered instruction as a visual model tool to facilitate students' conceptual understanding. Also, they can be used as a form of checking for understanding or as games and quizzes during differentiated instruction or remediation (Regan, Berkeley, Hughes, & Kirby, 2014). Briefly, virtual manipulatives provide greater opportunities for students with dyscalculia learner to learn by serving individual differences with personalized accessibility. Virtual manipulative proved to be better than the concrete manipulative on learning basic arithmetic among students with Dyscalculia at Primary level. It brings efficacy and enhancement in achievement and much scope in Basic arithmetic learning.

By way of promoting a multisensory interactive learning environment, teachers can help students with Learning Disabilities, particularly Dyscalculia to engage in their learning of mathematics. The use of virtual manipulatives through computer and mobile apps is a viable tool for teaching mathematical concepts and skills to students with LD. Virtual manipulatives can be integrated into teacher-delivered instruction as a multisensory tool to facilitate students' conceptual understanding. Evaluation in the form of games and quizzes during differentiated instruction or remediation (Regan, Berkeley, Hughes, & Kirby, 2014) makes learning and assessment more joyful and creative. Regardless of the instructional situation, teachers can monitor to make sure students have a meaningful and joyful learning experience.

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