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Conceptual Errors Encountered in Mathematical Operations in Algebra among Students at the Secondary Level

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Abstract

The present study investigates conceptual errors encountered in mathematical operations in Algebra among students at the secondary level. Survey method is used to select a sample of 320 students in different categories of schools, government, government-aided, corporation and private schools. A Diagnostic test is developed to assess the conceptual errors encountered in mathematical operations in Algebra. The results of the statistical analyses reveal that students in government-aided schools commit a significantly higher level of mistakes compared to students in other categories of schools. On comparing students in Tamil and English media, students in Tamil medium are found to encounter greater mistakes in Algebra compared to students in English medium. Likewise, boys are found to encounter greater level of errors in mathematical operations in Algebra.

Keywords: ***Conceptual errors, Mathematical operations, Diagnostic test***

1. Introduction

Education in the words of Dewey (1916) is a constant reorganizing or reconstructing of experiences. Education is chiefly concerned with developing and modifying behaviour patterns in human beings in the realms of thinking, feeling and acting. Education is the main instrument of change anywhere in the world and its importance is greater in the developing countries. The development of human resources depends on a well-organized educational system. 'The destiny of India is now being shaped in her class rooms' so begins the monumental report of the Education Commission, 1964-66. The Education Commission is firmly of the opinion that no reform is more important or more urgent than to transform education to endeavor to relate it to the life needs and aspiration of the people and thereby makes it a powerful instrument of social, economic and cultural transformation necessary for the realization of the national goals. Education should develop in our boys and girls, right attitudes towards life, men and things. The central goal of education is not just leading to

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read and write but to develop the abilities to think and reason. Reasoning is the heart of education. This is more explicit in the education of Science and Mathematics than other fields. All branches of Science and Mathematics thrive on reasoning logical explanation and thinking ability of Science and Mathematics take the pride to top list.

1.1 Mathematics

Mathematicians and layman have defined Mathematics in various ways, but all have agreed about the indispensable nature of the subject. They have accordingly described it as the back done of the society, mother of all Sciences and the handmaid to all arts and Sciences and thus have recognized its importance and omnipresence. Mathematics can be considered as a subject and processes, which contains rules of calculations, and processes, which go to help mankind in living a life of comfort and happiness. It contains everything in a very condensed manner and arranged logically which makes it easy for us to group and retain. It is the king of all Sciences and queen of all arts, which influence all branches of Science in particular. The study of Mathematics is considered, to be basic for the development of all other Sciences.

Mathematics forms the base and inner core of all scientific and technological progress. In fact, Mathematics underlines all that is good and beautiful, be it art, architecture or music. Mathematics also forms the basis of all discoveries and inventories and it has played a very important role in building up our civilization by perfecting all the Sciences. It gives a workable symbolism for the brief and precise expression of ideas to all Sciences. In the report of the Education Commission (1964-66) it is recommended that Sciences and Mathematics should be taught on the compulsory basis to all pupils as a part of general education during the first ten years of schooling. A difficulty in learning Mathematics is not generally a number based one but can be concept based or competency based. Some children learn to solve problems by mastery of steps in a procedure with a fixed order, and errors appear when the problem is presented in a different format or when the test is made up of a variety of problems. It is at this juncture that error analysis is done.

1.2 Algebra

Algebra is considered as very important branch of Mathematics. The word ‘Algebra’ is a corruption of the word “Algebra-al-muqubulah’ which refers to the operation of taking a

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quantity from one side of an equation to another, and changing its sign; and also to the process of subtracting similar quantities from both sides of an equation. The fundamental necessity for the teaching of Algebra is to give training in analysis and expression. Inspite of its utility it is commonly found that pupils show a kind of aversion to Mathematics and Algebra in particular. Many are of the opinion that learning Algebra is more difficult than learning arithmetic. One of the chief functions of the Mathematics teacher is to discover difficulties experienced by the pupils in learning concepts in Algebra and to overcome the difficulties.

1.3 Errors

'An error' is a concept of deviation from what is correct, right or true. If the student does not understand the mathematical concepts meaningfully, it is natural they will be committing errors in performing the operations. The errors are made due to misunderstanding of the concepts. Analysis is the process, which involves critically evaluating the students' errors for remediation. Analytical approach is the method of diagnosing difficulties, which seeks to identify the specific elements in learning ability that are weak and need remedial teaching. Diagnostic tests help to locate the areas of difficulties of the learner and are administered to locate the specific weakness in the skill or knowledge that are causing trouble and difficulties in learning. Unless the type of weakness is found it is difficult to correct it and prevent its re-occurrence.

2. Need for the Study

It is often pointed out that pupils experience difficulties involving problems in Mathematics, very particularly in Algebra. Teachers who have gone through examination scripts in Mathematics especially in Algebraic addition and subtraction often say that there is lack of grasp of essential principles, concepts and process concerned under the prescribed syllabus. Students experience great difficulty in their effective learning of the subject inspite of their best efforts being put in. The teachers should analyze the hard spots and by which teaching of the subject can be made more effective. Thus a need is felt to analyse the conceptual errors encountered in mathematical operations in Algebra among students at the secondary level.

The objectives of the present study are:

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(i) To investigate the significant difference between the levels in committing errors in mathematical operations in Algebra among students at the secondary level in different categories of schools;

(ii) To investigate the significant difference between the levels in committing errors in mathematical operations in Algebra among students in English and Tamil media at the secondary level in different categories of schools; and

(iii) To investigate the significant difference between the levels in committing errors in mathematical operations in Algebra among boys and girls at the secondary level in different categories of schools.

3. Reflections

In order to diagnose the errors in computation of Algebraic problems, it is essential to review critically the various studies made in this field. Further, a study of relevant literature is an essential step to get at a full picture of what has been done with regard to the problem under study. The literature reviewed pertaining to the present study have been complied and presented under appropriate headings.

3.1 Mathematical Operations

The mathematical operations namely, addition, subtraction, multiplication and division are the basic computational skills, each and everyone should possess in order to survive in the material world. Unless one understands the basic concepts behind these fundamental operations, one cannot learn any other topic in Mathematics. Many Mathematics educators have made researches on the misconceptions of the students belonging to different age groups, sex, and different categories of schools in Mathematics in different countries.

Sinha (1971) constructed a diagnostic test of arithmetic vocabulary for Grades VI, VII, and VIII with a view of detecting pupils' difficulties in the subject and to ascertain the nature, extent and cause of errors committed by them in respect of the concepts involved. Cox (1978) reported that among children who made systematic errors when adding or subtracting two digit numbers, 67% made addition error and 83% made the subtraction error. Researchers like Das and Barua (1968), Rastogi (1983), Sinha (1971) and Thakore (1980) have constructed diagnostic tests and suggested remedial measures for specific weakness in

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Mathematics. Fisehbein et al (1985) found that the errors, adolescents made in writing expressions to solve division word problems were consistent with misconceptions about decision that are logically equivalent to the constraints of the primitive models of decision. Graeber et al (1988) have suggested that pre-service teachers' explicit statements about operations and even successful calculations can mask misconceptions about division. Attainment in Mathematics is very much based on the mastery of fundamental skills. Sarala (1990) has analyzed the conceptual errors of secondary school students in learning selected areas in modern Mathematics has found that the number of errors are quite large, and these errors are influenced by sex, locality of the school, management of the school, intelligence, study habits and socio economic status.

Aguele and others (2010) conducted a study to determine the effectiveness of selected teaching strategies in the remediation of process errors committed by students in Mathematics in senior secondary schools. The study employed the quasi–experimental design. Sample for the study consisted of two hundred and seven (207) students drawn from six senior secondary schools randomly selected from the three hundred and sixty senior secondary schools in Edo State. The Diagnostic Test on Mathematics (DIATOM) was used to collect data for the study. Results of data analysis revealed that the direct instruction was a more effective strategy for the remediation of process errors committed by students in Mathematics. Sex and school location were shown not to have had any significant influence on the effectiveness of either strategy.

3.2 Algebraic Concepts

Students made all kinds of computational errors in solving mathematical problems-computational errors are not necessary the result of carelessness or not knowing how to proceed, it can be caused by students applying the 'failure strategies' (Ashlock, 1994). Research into errors provides a rich source of knowledge about the processes and influences involved in mathematical problem solving. Considerable research has been conducted into the nature and causes of errors in solving Algebraic problems.

Clement (1982) reported that a large number of Science-oriented college students were unable to solve a very simple kind of Algebras word problem. There errors were from two main sources: syntactic and semantic. Kamal (1986) attempted to characterize and compare the performance of successful and less successful students in the first year Algebra

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classes and found that the successful students tend to write equations for the complex problems by applying a familiar standard procedure without ensuring that fit applied to the conditions of the problem or not. In contrast, successful students applied the procedure after transforming the given problem states to new states that lent themselves to the application of the procedure. Moldavan (1986) found no significant difference between the two classes namely the experimental class who received additional instruction regarding 16 common errors and the control class who did not receive any instruction. Neal (1986) suggested that a list of common errors could be assembled from prior research and that when such a list is used in developmental courses to make students aware of their potential errors, instructions is more effective and learning is durable. Kieran (1987) encountered an analysis of the processes used in solving Algebraic equation and determining their equivalence in the early stages of learning. The effect of the analysis of errors on Algebraic achievement investigated by Hourlland (1987) has resulted with the finding that for each instructional unit, there was a significant difference in Algebra achievement due to students' ability.

Loh (1991) studied the levels of ability in solving Algebra word problems among 130 secondary two students. The results indicated that problem understanding and problem representation are the critical rate-determining steps in solving Algebra word problems. Philip (1992) concludes that implicit variable relationship problems were harder than explicit variables relationship problem among Algebraic variables. Kelly (1993) found that lack of expertise with mathematical content was a more frequent impediment to solving Algebra problems than problem solving deficiencies. Goodwin (1997) made a study to investigate whether error detection instruction improves students' confidence levels and or reduce anxiety. Selitto (1997) made a study that revealed that students in elementary Algebra struggled with the abstract notation of 'variable'. Theoretical implications of the study concluded that the characterization of an arithmetic approach and an Algebraic approach to the learning of equation solving is used to suggest a basis for a theory of Algebra learning. Liebenberg (1997) designed a diagnostic test to investigate the errors made by 40 students in simplifying very elementary Algebraic expression. Liebenberg reported that three error patterns occurred in the study, namely misinterpretation of symbolic notation, difficulty with the subtraction concept, and difficulty with the integers. Similarly, Demby (1997) focused on the types of procedures used by students in performing the task. Most of the procedures appeared spontaneous in the sense that they had not been taught in the class.

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Hall (2002a) investigated the errors made by 246 pupils in solving three to six linear equation questions. Transposing, switching addends and division are found to account for approximately three quarters of the total number of errors. Ayres (2000b) identified the errors committed by students on bracket expansion tasks as working memory load was not equally distributed over the four operations.

Sakpakornkon and Harries (2003) explored pupils' processes of thinking in simplifying Algebraic items. The main difficulties were dealing with negative signs and multiplying out the brackets. Muller et al. (2014) reported the results of a research with 333 freshmen students of Differential Calculus, for whom it was applied a test with questions about basic Mathematics. The question analysed involved basic Algebra. The students made mistakes in operations and Algebraic properties that are essential for the continuity of their studies in Calculus, especially to solve exercises of limits and derivatives. The main difficulties observed are related to the distributive property of multiplication over addiction.

Keeping all these reviews as the main view an attempt is made by the investigator to develop a diagnostic instrument and to identify the conceptual errors in mathematical operations in Algebra at the secondary level.

4. Formulation of Hypotheses

Based on the review of related literature and the objectives of the present study, the following hypotheses are formulated:

(i) There is no significant difference between the levels in committing errors in mathematical operations in Algebra among students at the secondary level in different categories of schools.

(ii) There is no significant difference between committing errors in mathematical operations in Algebra among students in English and Tamil media at the secondary level in different categories of schools.

(iii) There is no significant difference between committing errors in mathematical operations in Algebra among boys and girls at the secondary level in different categories of schools.

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5. Method of Investigation

5.1 Sample

Keeping in view the objectives and the hypotheses formulated for the present study a sample of 320 students at the secondary level are randomly selected from four different categories of schools, namely, government, government-aided, corporation and private schools.

5.2 Technique to Identify the Conceptual Errors

The technique used to identify the conceptual errors of students in computation of mathematical operations, includes oral interviews and discussions with the experienced secondary school teachers and college lecturers. These discussions helped to identify common areas of misunderstanding and conceptual errors and give rise to the development of ideas for further probes for developing a diagnostic test.

5.3 Diagnostic Test

The Diagnostic Test consists of VI parts. Part-I contains four objective type questions with four multiple-choice answers. The students are expected to tick the answer on the question paper itself and the techniques adopted here is to solve the problem mentally by identifying the type of expression within few seconds. A concept not understood by a student is taken as difficulty and omissions are also treated as difficulties. Each question is constructed so as to detect the errors made by the student by the developed concepts. Part-II consists four questions and the errors are diagnosed through multiple-choices under each question. Part III consists of six items to diagnose errors in addition. Similarly subtraction, multiplication and division errors are analysed by Parts IV, V and VI respectively with six items in each part. These items are framed to test whether the students are able to apply the concepts of operations in Algebra, because without application, the knowledge of concepts alone would not benefit the students. These sections were given to diagnose the errors with respect to the above concepts in addition, subtraction, multiplication and division.

The reliability of the Diagnostic Test is established on the basis of Spearman's Rank Correlation formula and is found to be 0.72, which is significant at 0.01 level. The validity of

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the diagnostic test is determined by computing correlation between the achievement in the school test and the diagnostic test. The 'r' value is found to be 0.74, significant at 0.01 level.

6 Analyses of Data Collected and Interpretation of Results

The data collected is quantified and statistical measures are employed in processing and analysing the data and the results are presented in the following tables.

Table 1: Analysis of Variance of Total Scores of Levels in Committing Errors in Mathematical Operations in Algebra among Students at the Secondary Level in different Categories of Schools

Source of variation	df	Sum of Squares	Mean of Sum of Squares	*F*-ratio
Between groups	3	1418.13	472.71	24.68**
Within groups	316	6053.11	19.15	
Total	319			

**significant at 0.01 level

In Table-1 for the analysis of variance, different categories of schools are considered as different groups. The *F*-ratio is 24.68, which is significant at 0.01 level. Thus there is a significant difference between the levels in committing errors in mathematical operations among students at the secondary level in different categories of schools.

Table-2: Statistical analysis of Means of Total Scores of Levels in Committing Errors in Mathematical Operations in Algebra among Students at the Secondary Level in different Categories of Schools

Variable	Sample Size	Mean	SD	SEM	SED	CR
Government-aided	80	14.3	4.6	0.51	0.65	7.69*
Government	80	9.3	3.7	0.41		
Government-aided	80	14.3	4.6	0.51	0.68	6.91*
Corporation	80	9.6	4.2	0.46		
Government-aided	80	14.3	4.6	0.51	0.74	7.02*

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Private	80	9.1	4.9	0.54		
Private	80	9.1	4.9	0.54	0.67	0.29^{NS}
Government	80	9.3	3.7	0.41		
Private	80	9.1	4.9	0.54	0.70	0.71^{NS}
Corporation	80	9.6	4.2	0.46		
Government	80	9.3	3.7	0.41	0.61	0.49^{NS}
Corporation	80	9.6	4.2	0.46		

**Significant at 0.01 level
NS-Not Significant
SD-Standard Deviation
SEM-Standard Error of Mean
SED-Standard Error of Difference
CR-Critical Ratio

From Table-2 it is evident that there is a significant difference between the levels in committing errors in mathematical operations in Algebra among government-aided and government; government-aided and corporation; government-aided and private schools. It is also seen that there is no significant difference between the levels in committing errors in mathematical operations in Algebra among private and government; private and corporation; government and corporation school students at the secondary level.

Table-3: Statistical Analysis of Means of Total Scores of Levels in Committing Errors in Mathematical Operations in Algebra among Students in English and Tamil Media at the Secondary Level in different Categories of Schools

Variable	Sample size	Mean	SD	SEM	SED	CR
Tamil Medium	120	11.50	4.00	0.36	0.51	2.74**
English Medium	200	10.10	5.20	0.36		

**Significant at 0.01 level
SD-Standard Deviation
SEM-Standard Error of Mean
SED-Standard Error of Difference
CR-Critical Ratio

The mean and standard deviation of scores of levels in committing errors are 11.50 and 4.00 respectively for Tamil medium and 10.10 and 5.20 respectively for English medium students at the secondary level in different categories of schools. The critical ratio is 2.74, which is significant at 0.01 level. Thus the Tamil medium students are in a higher level in

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committing errors in mathematical operations than English medium students at the secondary level in different categories of schools.

Table-4: Statistical Analysis of Means of Total Scores of Levels in Committing Errors in Mathematical Operations in Algebra among Boys and Girls at the Secondary Level in different Categories of Schools

Variable	Sample size	Mean	SD	SEM	SED	CR
Boys	160	11.80	4.40	0.34	0.51	4.50**
Girls	160	9.50	5.00	0.39		

**Significant at 0.01 level
SD-Standard Deviation
SEM-Standard Error of Mean
SED-Standard Error of Difference
CR-Critical Ratio

The mean and standard deviation of scores of committing errors in mathematical operations in Algebra are 11.80 and 4.40 respectively for boys 9.50 and 5.00 respectively for girls at secondary level in different categories of schools. The critical ratio is 4.50, which is significant at 0.01 level. Thus the girls are higher in level in committing errors in mathematical operations in Algebra than boys at the secondary level in different categories of schools.

5. Conclusion

Educators have been investigating and trying to identify the conceptual errors for more than hundred years. But in the educational research, it has been considered important and brought to the notice of the research field only in the last decade. The students, who are very good and confident in the fundamental operations in arithmetic, find the same operations in Algebra difficult. The reason is the misunderstanding of the concepts of the number system and misinterpretation of the mathematical concepts. The reason for the misunderstanding and committing a lot of errors in the operation must be found out. Diagnosis of students' difficulties or students' misunderstanding may help the teacher, the approach effective strategies to develop meaningful learning in the educational setting. In these lines the present study has been attempt to study the conceptual errors in mathematical operations in Algebra among middle school students. The main objective of the present study

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was to develop a suitable diagnostic tool to identify the students' conceptual errors in mathematical operations in Algebra. It was also to find the significant difference in conceptual error scores of students belonging to different categories of schools and different media of instruction. For the present investigation 160 boys and 160 girls studying in different categories of schools, namely, government, government-aided, corporation and private schools were chosen. The major assumption is that the meaningful learning will be affected due to the errors committed by students in mathematical operations. With the help of the instrument constructed and the oral interviews and discussions held with the experienced school teachers and college lecturers common areas of misunderstanding and conceptual errors were identified. The instrument has been administered to the sample according to the procedure and data collected has been subjected to statistical analysis.

The major findings of the analyses revealed that there is a significant difference between the levels in committing errors in mathematical operations in Algebra among students at the secondary level in different categories of schools. These errors may be due to lack of fundamental knowledge in mathematical operations. Thus the concepts in fundamental operations should be exercised in the minds of students at an early age. It was also found that the Tamil medium students are higher in level in committing errors in mathematical operations in Algebra than English medium students and the girls are higher in level in committing errors in mathematical operations in Algebra than boys at the secondary level in different categories of schools.

As the conceptual errors help the teacher to understand the students' difficulties and evaluate the level of knowledge among students, it is absolutely essential that the teacher must be aware of students' pre-conception and textbook errors. The teacher must be more effective to teach Algebra to the students patiently and also must understand the minds of the children to handle Algebra skillfully. More home assignments must be given to the pupils and periodical checking and diagnosis of the understanding of the concepts immediately after the teaching, may reduce more errors. Rigorous practice and drilling at the initial stage will definitely increase the depth of understanding and results in good learning to fetch good results. Innovative methods and technique must be adopted to make both teaching and learning effective in Algebra. The students should be given a clear idea about each and every step in Algebra and every mathematical operation must be taught logically in steps.

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