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Construction and Standardization of Test of Algebraic Reasoning (TAR) For Class VIII Students

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Abstract – The main objective of the present paper is to report the process of development and Standardization of test of algebraic reasoning (TAR) for grade VIII school students. Content for the test development is selected from the NCERT text book and U.P Basic Shiksha Parishad board. Initially a multiple choice test of 68 items from VIII grade Mathematics syllabus was selected and designed on the selected topics in such a way to test the algebraic reasoning of the students in algebra. For trying out the preliminary draft of the test of algebraic reasoning, the test was administrated to a sample of 200 grade VIII students of Varanasi district. The difficulty value (DV) and discriminating power (DP) of the test items were determined by adopting Kelley's (1939) method. On the basis of the DV and DP the preliminary draft of the test was modified. In total 32 items having difficulty value (DV) ranging from 0.20 to 0.75 and the items ranging from 0.40 and above as the discriminating power (DP) were retained for the final test.

Key Words: Algebraic Reasoning, Algebra, Standardization.

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INTRODUCTION

Mathematics is a subject, which requires the higher order thinking process as compared to any other school subjects. In mathematics algebra offers the abstractness from the very beginning stage of learning algebra as well as nature of algebra is different from the arithmetic, which makes it more difficult to handle. Since algebra is considered as a gateway for the higher mathematics, it plays a vital role in the development of basic cognitive abilities like reasoning, thinking, using pattern-based thinking, understanding real-world phenomena and transforming it into the equations. Major aim of mathematics teaching is to develop the reasoning ability among the students to make them competent in mathematical skills; means to develop the ability to understand, judge, solve, and use these mathematical abilities across a variety of mathematical situations (Niss, 2007). "Developing children's abilities for mathematisation is the main goal of mathematics education" (NCF, 2005).

National curriculum framework -2005 has further divided aims of mathematics learning into two categories; the narrow aim of school mathematics and higher aim. According to NCF-2005 "narrow aim is to develop useful basic capabilities relating to numeracy–numbers, number operations, measurements, decimals and percentages. The higher aim is to develop the child's resources to think and reason mathematically, to pursue assumptions to their logical conclusion and to handle abstraction" When it comes to the algebra, the challenge becomes tougher due the increase in the abstractness. Every school subjects has different nature, similarly mathematics also has a nature which emphasis on the basic idea of development of the reasoning ability of the child and ability to handle abstraction. Similarly when it particularly come to Algebraic Achievement, it is highly dependent on prior understanding and attainment of concepts of arithmetic. Algebraic reasoning can be used as an approach to relate the arithmetic and algebra; it can be act as cantilever to improve the algebra learning by using the prior knowledge of arithmetic. Since the nature of mathematics is hierarchical its upcoming concepts highly relays on the previous concepts that have been taught to the learners. As, NCTM (2000) also suggests that successful preparation of students for learning algebra can be done, if we begin teaching them to think algebraically in the early years.

This approach is a crucial issue to be understood by the school teachers those who are actually practicing the algebra teaching and learning at the grass root level i.e. elementary level of schooling. Along with this teaching of mathematics have some certain aims at the various levels of learning as per the nature of the subjects. Along with this the position paper on teaching of mathematic, NCERT, Also laid emphasis on mathematics for all with the approach to make the students enjoy mathematics learning. Students should not only understand the computation they should understand the basic structure of the mathematics. In the light of this to test the algebraic reasoning of the class VIII student's researcher has developed the test of algebraic reasoning and development process has been discussed below.

ALGEBRAIC REASONING

"Algebraic reasoning is a process in which students generalize mathematical ideas from a set of particular instances, establish those generalizations through the discourse of argumentation, and express them in increasingly formal and age-appropriate ways."(Kaput & Blanton, 2005)

Algebraic Reasoning at the elementary level is the study of mathematics with a focus on operations (=, >, <) functions, polynomial, and equations rather focusing only on the numbers and its computations. Algebraic reasoning can be used especially at the transition phase of learning algebra. This transition phase basically arrives at the grade 6 level in our schooling system (NCERT text book for mathematics class VI page no. 221). Kaput (1999) stated that algebraic thinking come into view when establishment of generalizations about data and mathematical relationships occurs during the processes of conjecturing, relating , and expressing them in a more concrete form, like establishing a equation , creating an inequality and solving words problems. The goal of using algebraic reasoning at initial algebra learning is to develop critical thinking skills among the students that they can apply these critical skills to the daily life problems. Solving a various mathematical problems requires a performance as consisting of different skills such as reversing processes (Wagner & Zimmermann, 1986) and problem solving (Gavin et al., 2007). Similarly handling the various mathematical problems requires the various skills. Algebra learning also requires the some basic skills to handle the algebraic problems like understanding the patterns, understanding the symbolic structure, ability to form equations and use it in their daily life along with the and ability to use these skills to the various complex situations of mathematics learning. Algebraic reasoning can be very significant in fulfilling the cognitive break between the arithmetic and algebra as well as fruit full in establishing the linkage between the arithmetic and algebra (Chaurasia, 2016). It can also be used as cognitive support for introducing and for sustaining the discourse of school algebra (Kieran, 1996). In the present research researcher has tried to identify such dynamic components of algebraic reasoning to develop the test of algebraic reasoning thorough which level of algebraic reasoning used by the students in solving the different mathematical questions can be measured. In terms of this process of identifying the dimensions of algebraic reasoning researcher has done extensive review of literature and initially identified the twelve dimensions of algebraic reasoning and prepared an assessment questionnaire for the experts from the fields of mathematics education. With the help of this questionnaire investigator has obtained the choices of various experts and teachers reading the suitability of the dimensions and content for the test. After collecting the responses regarding the dimensions and content for the test investigator has selected the nine dimensions of algebraic reasoning and contents (see table 1). Nine dimensions identified for the development of test are (1) Doing –Undoing (Reversibility) (2) Abstracting From Computation (3) Building Rules to Represent the Function (4) Structural Understanding/ Understanding of Growing Patterns (5) Mathematical Generalizations (6) Understanding Relation between the Operations and Function (7) Analyze Patterns and Relationship (8) Use of Conjectures, Coordination of Numeric and Spatial Structures (9) Thinking about Spatial Configuration of the Sequence Terms /or Other Structure. On the basis of above nine finalized dimensions of algebraic reasoning.

NEED FOR THE TEST OF ALGEBRAIC REASONING

The prime purpose of investigator regarding the development of the test of algebraic reasoning is to develop a kind of test with the help of which algebraic reasoning of the class VIII students can be tested. In this test questions are from the algebra but still having prime focus on the aspect of algebraic reasoning. Questions are directly based on the dimensions identified by the investigator. Keeping the focus on this view investigator develops all the items of the test in such a way that all items are accomplished to trial the different dimensions of the algebraic reasoning. Before development of the test, investigator has done the extensive review on the availability of various tests for reasoning as well as different test available for mathematics and various components. Here let us be very clear in comparing the algebraic achievement and algebraic reasoning. Algebraic achievement is a measure of concept attainment taught in algebra whereas algebraic reasoning is approach which can be utilized to solve the various problems of algebra and append to the algebraic achievement. During the review investigator has found various tests which can be used to measure the different aspects of mathematics learning among different age groups. Mixed Type Group Test of Intelligence by Mehrotra, Cognitive Ability

Test by Gupta and Lakhani, Reasoning Ability Test by Ahmed Bhat and Govilt this test can be administered on secondary school students and Reasoning Ability Test by Dubey applicable for 12 to 17 years students and Sanjay Vohra Davis's Battery of Differential Abilities. Among all this available test and tools none of the test has fulfilled the requirement of investigator. Therefore, the need of the present test was felt. Generally in the researches to standardized test were used to collect data. To obtain authentic data and result we need to use standardize test or tool. Therefore investigator has gone through the rigorous international standards and patterns of test standardization.

PURPOSE OF THE STUDY

The purpose of the study was to develop and validate a test of algebraic reasoning (TAR) to measure class VIII students algebraic reasoning, carry out item analysis (difficulty and discrimination index) and estimate the reliability coefficient of the test of algebraic reasoning.

RESEARCH METHOD

The present study is basically to design, develop and validate test of algebraic reasoning. In the present study analysis of text books and syllabus was done, content selection was done and items based on it was developed. Basically it was instrumentation in nature and it was suitable to assess the algebraic reasoning among the class VIII students. The descriptive survey research method is considered appropriate for this study as it would help to obtain first-hand information regarding the students' level of acquisition of algebraic reasoning. The population comprised of class VIII students of Central Board of Secondary Education (CBSE) School in Uttar Pradesh state. The research sample used was made up of two hundred (200) students drawn from four (04) sections of secondary schools from Varanasi district of Uttar Pradesh state.

DEVELOPMENT AND STANDARDIZATION OF TEST OF ALGEBRAIC REASONING (TAR) EXPLORATORY STAGE

In this stage, items were constructed by the investigator, after identifying the main content for the algebraic reasoning. In this stage investigator reviewed text book of N.C.E.R.T. and U.P. Board to select the content at the initial level.

(A) SELECTION OF CONTENT FOR THE TEST OF ALGEBRAIC REASONING.

The investigator has prepared an assessment questionnaire for the school teachers of mathematics and research scholars working in the field of mathematics education to select the content for the test of algebraic reasoning. On the basis of that final content those were selected for the test of algebraic reasoning, test was prepared. The final selected content are as following:-

SELECTED CONTENTS FROM CBSE BOARD SCHOOLS AND U.P. BASIC SHIKSHA PARISHAD BOARD FOR CONSTRUCTION OF TEST OF ALGEBRAIC REASONING (TAR)

Table 1

S.NO	(CONTENT)	NUMBER OF QUESTIONS
1.	**Fundamental Concepts of Algebra**	**7**
a	Constant and Variables	2
b	Introduction to Polynomials	2
c	Degree of a polynomials in one variable	1
d	Degree of a polynomials in two or more variable	1
e	Addition and Subtraction of Polynomials	1
2.	**Algebraic Expression**	**8**
a	What are Expressions?	1
b	Terms, factors, coefficient	1
c	Monomials, binomials and polynomials	1
d	Addition and subtraction of algebraic expressions	1
e	Multiplication of a monomial by a monomial	1
f	Multiplying three or more monomials	1
g	Multiplying a monomial by a polynomial	1
h	Multiplying a monomial by a trinomial	1
3.	**Algebraic Identity**	**8**
a	Applying Identities to solve various problems	8
4.	**Exponents and Powers**	**7**
a	Introduction of exponents	3
b	Powers with negative exponents	2
c	Laws of exponents	2
5.	**Factorization I**	**7**
a	Monomials factors	2
b	Factors of naturals numbers	2
c	Introduction of factorisation	1
d	Methods of common factors	1
e	Factorization by Regrouping Terms	1
6.	**Factorization II**	**7**
a	Factorization using Identities	2
b	Factors of the form (x+ a) (x+ b)	2
c	Factorizing trinomials of the form ax^2+bx+c	2
d	Division of Algebraic Expression	1
7.	**Linear Equations**	**5**
a	In equations in one variable	3
b	Solving equations which have linear expressions on one side and numbers on the other side	2
8.	**Applications to Linear Equations**	**7**
a	Solving equations having the variable on both sides	4
b	Words problems based on linear equations	3
9.	**Introduction to Graphs**	**12**
a	Introduction to Coordinates and	3

	Quadrants	
b	A bar graph	3
c	A Pie graph (on a circle-graph)	2
d	A histogram	2
e	A line graph	2
	Total	68

(B) IDENTIFICATION OF THE DIMENSIONS FOR THE CONSTRUCTION OF ITEMS OF TEST OF ALGEBRAIC REASONING

Nine dimensions of algebraic reasoning were finalized for the development of test of algebraic reasoning those dimensions have been already discussed above. On the basis of these dimensions all items were prepared from the selected contents.

PREPARATORY STAGE

(A) PREPARATION OF THE FIRST DRAFT

The first draft of the Test of algebraic reasoning (TAR) consisted of total 68 multiple choice questions, all the items developed form the selected content was designed in such a way that they intended to promote the algebraic reasoning. Every items from the each content selected was given approximately equal weightage only introduction to the graphs has been given more weightage and total 12 questions were selected from it. Overall it can be said that eminence combination of contents and dimension of algebraic reasoning has been done of the overall construction of the test.

Each question has one correct response out of four given responses. After developing the items of the test, first draft was given to experts in the field of mathematics education and teachers those who were teaching mathematics at the higher secondary level for their comments, feedback and suggestions. After the suggestion and feedbacks from the experts responses of some questions are modified and language was changes in such a way to make easier for the learners to understand and finally all 68 items were retained in second draft.

(B) SCORING KEY

Scoring key was developed with the help of 3 mathematics teachers (2 PGT and 1 TGT) by solving each question one by one; along with the cross verification of each and every answer was done by the investigator himself before the final drafting of the answer sheet.

(C) PILOT STUDY

Then after the preparation of first draft of the test, initially first draft of **Test of Algebraic** Reasoning was administered on a sample of 25 students of class VIII of Varanasi city. After administration the total time taken was decided. Language ambiguity was modified again as per the demand of the some students. Finally, total 68 items was again retained in the test with some minor corrections in language and framing of the question especially in the items related to the algebraic expression and introduction to graphs. The purpose to administer the TAR was to find out the appropriateness of the level of difficulty of items, language ambiguity, and adequate content, simplicity of the item's statements' and learners friendliness.

(D) SECOND DRAFT OF THE TEST

All the items of the first draft of test of algebraic reasoning were retained in the second draft with few modifications in the language of some items, which are found vague and difficult during pre-try-out as well as some very hard level questions were also removed. The second draft of the tool had following parts:-

INSTRUCTIONS FOR ADMINISTRATION

An introductory statement was given to declare the purpose and significance of the study and the necessary instructions were also given to fill up in the test.

THE TITLE OF THE TEST

Since test was develop to check the algebraic reasoning of the students so a suitable title **Test of** Algebraic Reasoning was decide for the test**.**

THE DEVELOPMENT STAGE

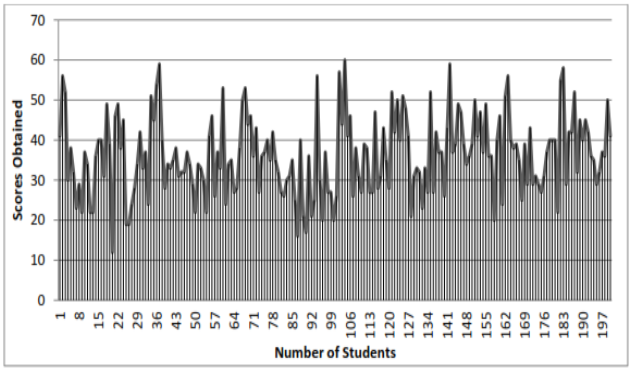
(A) SECOND TRY OUT OF THE ITEMS:

In the final try out, the TAR was administered on a sample of 200 students for the purpose of item analysis. During the administration of TAR, it was emphasized that no item should be omitted and the respondents were requested and encouraged to respond honestly on every item of the test.

(B) ITEM ANALYSIS:

The investigator used 200 students of class VIII from SOS Hermann Gmeiner School, Varanasi and administers the test over all of them for item analysis. The individual's scores for all the 200 samples were obtained and they were arranged from the highest to the lowest score. After that the investigators took top 27% of the sample: the high scorers, and the bottom 27% - the low scorers. The high and low groups, thus selected formed the criterion groups; each group consists of 54 answer sheets.

GRAPHICAL ILLUSTRATION OF DISTRIBUTION OF STUDENTS' SCORE IN THE TEST OF ALGEBRAIC REASONING



ITEM SELECTION:

DIFFICULTY INDEX OF AN ITEM:

The difficulty index of an item is represented by the percentage of students who responded to it correctly. It was calculated using the formula.

D.I. = U + L/2N

Where, U = Number of correct responses in the upper group

L = Number of correct responses in the lower group

N = Number of students in both the group.

DISCRIMINATION POWER OF AN ITEM:

The discriminating power of an item indicates the measure of the extent to which an item discriminates or differentiates between subjects who do well on the overall test and those who do not do well on the overall test. The discriminating power of the item was calculated by the formula.

D.P. = U – L/N

Where, U = Number of correct responses in the upper group

L = Number of correct responses in the lover group

N = Number of students in both the group.

SELECTION OF ITEMS:

Based upon the above formulae for the difficulty index and discrimination power of each item of TAR was worked out. Any item whose discriminating power is above 0.30 should be considered as a reasonably good item (Ebel, 1966). In the present investigation, only such of those items whose difficulty indices ranged from 0.25 to 0.75 and whose discriminating power was above 0.40 were selected. The table 3 presents the details of this exercise.

TABLE SHOWING THE DV AND DP VALUES FOR ITEM ANALYSIS AND SELECTED ITEMS FOR TEST OF ALGEBRAIC REASONING (TAR)

Table: 3

ITEM	D.V.	(0.25-0.75)	D.P.	0.40 AND ABOVE	FINAL RESULT
Item 1	0.21	R	0.17	R	R
Item 2	0.49	A	0.17	R	R
Item 3	0.52	A	0.19	R	R
Item 4	0.17	R	0.11	R	R
Item 5	0.32	A	0.43	A	A
Item 6	0.16	R	0.02	A	R
Item 7	0.52	A	0.22	R	R
Item 8	0.51	A	0.24	R	R
Item 9	0.45	A	0.43	A	A
Item 10	0.49	A	0.28	R	R
Item 11	0.49	A	0.46	A	A
Item 12	0.44	A	0.48	A	A
Item 13	0.37	A	0.41	A	A
Item 14	0.39	A	0.26	R	R
Item 15	0.32	A	0.31	R	R
Item 16	0.43	A	0.44	A	A
Item 17	0.36	A	0.54	A	A
Item 18	0.36	A	0.50	A	A
Item 19	0.39	A	0.59	A	A
Item 20	0.35	A	0.44	A	A
Item 21	0.51	A	0.39	R	R
Item 22	0.61	A	0.33	R	R
Item 23	0.50	A	0.19	R	R
Item 24	0.34	A	0.43	A	A
Item 25	0.56	A	0.33	R	R
Item 26	0.51	A	0.28	R	R
Item 27	0.54	A	0.30	R	R
Item 28	0.52	A	0.41	A	A
Item 29	0.61	A	0.11	R	R
Item 30	0.57	A	0.07	R	R
Item 31	0.44	A	0.50	A	A
Item 32	0.36	A	0.39	R	R
Item 33	0.58	A	0.43	A	A

Item 34	0.32	A	0.39	R	R
Item 35	0.47	A	0.43	A	A
Item 36	0.52	A	0.26	R	R
Item 37	0.50	A	0.52	A	A
Item 38	0.56	A	0.31	R	R
Item 39	0.46	A	0.37	R	R
Item 40	0.38	A	0.39	R	R
Item 41	0.43	A	0.41	A	A
Item 42	0.60	A	0.43	A	A
Item 43	0.40	A	0.43	A	A
Item 44	0.48	A	0.26	A	A
Item 45	0.47	A	0.46	A	A
Item 46	0.44	A	0.39	R	R
Item 47	0.56	A	0.19	R	R
Item 48	0.44	A	0.41	A	A
Item 49	0.44	A	0.31	R	R
Item 50	0.47	A	0.31	R	R
Item 51	0.53	A	0.31	R	R
Item 52	0.56	A	0.52	A	A
Item 53	0.52	A	0.30	R	R
Item 54	0.51	A	0.31	R	R
Item 55	0.37	A	0.41	A	A
Item 56	0.56	A	0.41	A	A
Item 57	0.57	A	0.33	R	R
Item 58	0.58	A	0.24	R	R
Item 59	0.48	A	0.41	A	A
Item 60	0.54	A	0.22	R	R
Item61	0.28	A	0.22	R	R
Item 62	0.41	A	0.30	R	R
Item 63	0.42	A	0.46	A	A
Item 64	0.43	A	0.44	A	A
Item65	0.44	A	0.48	A	A
Item 66	0.41	A	0.37	R	R
Item 67	0.47	A	0.43	A	A
Item 68	0.47	A	0.57	A	A

Note: - A- denotes the items selected/accepted; R- denotes the items not selected/ rejected

FINAL STAGE:

(a) TIME LIMIT:

In the exploratory stage 40 minutes was allotted to respondents. But during the administration of the second draft it was noted that most of the respondents finished the questions within 30 minutes. Therefore, 35 minutes time was allotted for the final form of the test.

RELIABILITY AND VALIDITY OF THE TEST OF ALGEBRAIC REASONING:

In the present study, investigator also established the reliability and validity of the test of algebraic reasoning. The details are as follows:

RELIABILITY OF THE TEST OF ALGEBRAIC REASONING:

In the present study reliability of the test of algebraic reasoning (TAR) has been established with the help of two methods, split half reliability method and K-R 20 reliability method The results are presented below in table 2

Table 2

MEASURING TOOL	RELIABILITY COEFFICIENT	
Test of Algebraic Reasoning	Split-half Reliability of Test of Algebraic Reasoning	K-R 20 Reliability of Test of Algebraic Reasoning
Value of reliability coefficient	0.88	0.87

In this way the TAR was found to be reliable for measuring the algebraic Reasoning of class VIII students.

VALIDITY OF THE TEST OF ALGEBRAIC REASONING

For determining the validity of the test of algebraic reasoning, content and construct validity was established.

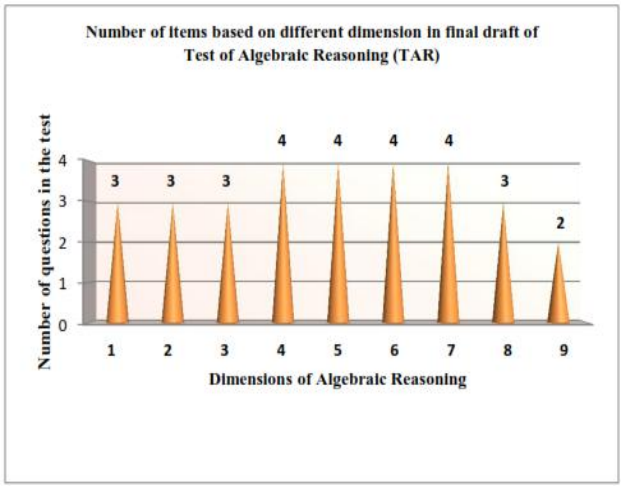
(a) CONTENT VALIDITY:

Here the content validity of test of algebraic Reasoning was decided on the basis of judgment and feedbacks of experts from the field of education, mathematics and mathematics education. All the items were tested by the each of the expert from all the fields , they have examined all the items as per the relevancy of the content and reported it appropriate, along with this relevancy of the items were also tested during the first try out.

Hence the 'Test of Algebraic Reasoning' may be considered to have satisfactory content validity.

NUMBER OF ITEMS BASED ON DIFFERENT DIMENSION IN FINAL DRAFT OF TEST OF ALGEBRAIC REASONING (TAR)

Serial no.	Dimension of Algebraic Reasoning	Number of items based on dimensions in test
1.	Doing –Undoing (Reversibility)	3
2.	Abstracting From Computation	3
3.	Building Rules to Represent the Function	3
4.	Structural Understanding/ Understanding of Growing Patterns	4
5.	Mathematical Generalizations	4
6.	Understanding Relation between the Operations and Function	4
7.	Analyze Patterns and Relationship	4
8.	Use of Conjectures, Coordination of Numeric and Spatial Structures	3
9.	Thinking about Spatial Configuration of the Sequence Terms /or Other Structure	2



FINAL DRAFT OF THE TEST OF ALGEBRAIC REASONING (TAR)

The Final form of the test of algebraic reasoning (TAR) consists of 32 questions 1 mark for each correct answer and 0 marks for each wrong answer. A maximum score for the test is 30 and minimum score is 0. The time limit for completing the full test is 30 minutes.

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