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CONSTRUCTION AND STANDARDISATION OF A MATHEMATICAL CREATIVITY TEST FOR SECONDARY STUDENTS

Abstract:

Researcher employed survey method and took 800 secondary students (class IX and X) from different English medium schools from both urban and semi- urban area in West Bengal as sample. Present researcher were influenced by SI model proposed by Guilford(1956) and initially attempted to construct this test consisting of 54 items under both divergent and convergent thinking abilities.

After that items were reviewed and carefully edited on the basis of expert's judgment and pilot test results and subjected to item analysis. Some items were rejected and rests (33 items) were accepted All the characteristics (reliability, validity etc.) were verified for accepted items and norms were developed. This test would be very helpful in the field of educational and vocational guidance and counseling by measuring Mathematical creativity of secondary students.

Keywords: *Convergent Thinking, Divergent Thinking, Mathematical Creativity, SI model, Standardisation.*

Introduction:

At present due to unremitting scientific and technological advancements, our lives have become fast-paced, complex and competitive. So this 21st century youth requires a creative mind and many sets of skills in order to cope up with and get success in work and life. One of the important skills is to have students think and act creatively in all subjects (Higginson, 2000; Runco, 2004; Torrance, 1982).
Mathematics is generally used for a variety of practical purposes (to solve different practical and challenging problems) and also for its intrinsic interest. Learning to know our creative ability, mainly creative ability in mathematics is one of the most significant aspects of our life. In this study, attempt has been made to construct and standardize a "test on mathematical creativity ", to identify students having Mathematical Creativity at secondary level.

Many researcher defined creativity as "the ability to produce work that is both novel (i,e originality unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)" (Sternberg and Lubart 1999 p.3).

A similar definition was given by Poincare (1913) for mathematical creativity. According to this definition mathematical creativity requires creating something new and useful. He emphasized the role of choice to pursue useful new ideas in his definition. According to Ervynck (1991), "mathematical creativity is the ability to create mathematical objects, together with discovery of their mutual relationship".

Creativity is not only considered a necessary skill for the business world or in the field of technology and scientific invention but also to mathematicians (e.g. Poincare 1913, Sriraman 2004 etc.). This is because mathematics forms the core of most technological innovations and development. Now on this ground the most burning questions which can be raised are:

1. How one can understand the present level/status of student's mathematical creativity? (Before or after implementing teaching strategies)
2. How one can measure the mathematical creativity or what should be the indicators (Detail about fluency, flexibility and originality) of the student's mathematical creativity?
3. What can be the proper guide to prepare a most appropriate Mathematical creativity test?

These are the most hunting questions what lead the present researcher to prepare a mathematical creativity test for secondary school students.

Objective of the study:
To construct and standardize a test on Mathematical Creativity for secondary pupils.

Sample and sampling techniques:
Here population will be constructed by the 800 pupils of class IX and X. The sample would be drawn using random stratified sampling method from different English Medium schools (W.B.B.S.E., I.C.S.E. and C.B.S.E.) in west Bengal.

Tools used:
1. A test on Mathematical Creativity to be standardized by the researcher.
2. An Aptitude test for Mathematics constructed and standardized by the researcher.

Construction of the test on mathematical creativity:
There are some creativity tests in India and also abroad which are used to measure creativity in general (Example of some such tests are, tests of Guilford, 1967;Torrance, 1966 and 1990;Passi, 1971 and 1978; Mehdi, 1973 etc).Some test like test of Majumder, 1974; Singh, 1981; Misra, 1986; Hu and Adey, 2002; Sen and Mukhopadhyay, 2009 help in measuring scientific creativity. Some refreshers worked on measuring creativity in specific field like creativity in Physics or creativity in chemistry or creative problem solving ability in mathematics (Michell A. Schrauth,(2014); Makiewicz, (2004); Balka, D.S.,(1975); Davis, M.S.,(1971); Kim, H.W.,Kim, M.S.,and Song, S.H.(1996); Kim, H.W.,Kim, M.S., Bang, S.J., and Hwang, Dong- jou.(1997); Hayloc, D.W.(1987)). But there are very few researchers (in comparison to research in measuring creativity in general) who have researched in this field. Sen and Mukhopadhyay (2009), constructed a test to measure creativity in Physics for higher secondary students. There is lack of same type of tests to measure Mathematical creativity, particularly for secondary students. Inadequacy in availability of such tests in India has made it necessary to construct a test to measure mathematical creativity for secondary school students.

Item Construction:
After initial identification of the different types of creative abilities, items of each type were constructed accordingly. Effort was given to construct the items in such a way that the respondents would get the scope to apply their mathematical knowledge to attempt the items successfully in diverse ways. Content area from where these items were mostly selected is secondary school mathematics curriculum. Two subject experts in the field of mathematics and education were consulted at the time of item construction along with their types and structure.
After a fruitful discussion with the experts the selected items were administered on the pre-try out group of 200 students from one Government and one private English medium school(who have completed the syllabus of class IX and X), in and around Kolkata. On the basis of the feedback obtained from this administration of the test, language and content ambiguity of the items were corrected. Different durations were found suitable for different items, as some items were close ended and some were open ended type.
This preliminary trial helped the researcher to prepare the instruction in detail and provide necessary and relevant examples for the final version of the test. This revised version of the test was used for further analysis of the items and administered on 800 students from both urban and semi urban area.

Item Analysis:
Since both the divergent thinking type and convergent thinking type items were incorporated in this mathematical creativity test so different methods will be appropriate for these two different types of items for item analysis.

Construction of Scoring Key:
For Divergent Items:
All the divergent type items were scored for the fluency, flexibility and originality. For this purpose researcher prepared a scoring key beforehand on the basis of result obtained from the pre try-out group. The scoring principles followed by the researcher for this purpose are given below:
1. Fluency: Total number of valid responses given by a student for a particular item.
2. Flexibility: The number of switch over of responses to different categories or number of spontaneous shifting of responses between every two successive categories.

3. Originality: For scoring of originality those rare responses were considered which were given by only 27% or less students of the sample. Then these 27% responses were graded using 5-point grading principle as shown below (Table 1).(V.P. Sharma and J.P. Shukla (1971) also used 5- point scale but unusual responses has been defined as that response which has a probability of occurrence to the extent of 5% in place of 27%.).

Table 1: Assessment of originality scores.

The rare 27% responses	5-Point Grading Scale	Percentage of Responses	Weight assigned for Originality Score
	Upper 7%	0% to 2%	4
	Next 24%	Above 2% to 8.5%	3
	Middle 38%	Above 8.5% to 18.5%	2
	Next 24%	Above 18.5% to 25%	1
	Lower 7%	Above 25% to 100%	0

According to the above mentioned table, originality score of each response for a particular divergent type item was considered. All the raw scores obtained for fluency and flexibility as mentioned above were further converted into the corresponding grade point using the principle of 5-point grading to getting similar scores as originality. Then all the grade point obtained as a fluency, flexibility and originality for a particular item were added together to get the total score of that divergent item for further analysis.

For Convergent Items:

For all the convergent items, 2-point scale was adopted by the researcher. Here simply, score '1' was assigned for each correct response and '0' for each incorrect response. Now, each of those raw scores obtained by 2-point scale was converted into the corresponding 5- points scale using principle of conversion of scores one scale to another scale to get the final grading. All these grade points were added to get total score of all convergent items.

Finally the total grade point obtained from divergent items were added to total grade point obtained in convergent items, in order to determine the overall score obtained by a particular student in a complete test of Mathematical creativity (Mukhopadhyay ,2009).

Final Consideration of Items:

The item discrimination was calculated in terms of a t-ratio taking the upper and lower 27% cases of the sample. Items were only considered for the final form of the test if t –value is significant at 0.01 level or less (HU and Adey, 2002; Sen and Mukhopadhyay, 2011; Sharma and Shukla, 1971).

Table 3: t- Ratio of Divergent Type items (N= 800)

This result shows that different divergent items have widely varying t- ratio but most of those items were found to be significant at 0.01 and 0.05 level of significance. The researcher excluded all those items which were

Item No.	Mean Score		Standard Deviation		t	p
	Upper Group (N_U)	Lower Group (N_L)	Upper Group (σ_U)	Lower Group (σ_L)		
1 (a)	14.95	6.46	5.233	3.347	8.69	0.02
1 (b)	8.80	3.47	4.164	2.470	6.95	.001
2 (a)	6.74	3.67	2.59	1.422	7.99	.000
2 (b)	26.22	4.79	4.16	3.08	2.10	.000
2 (c)	4.62	1.125	2.87	1.159	7.15	.000
4 (a)	10.35	5.61	3.03	3.14	8.25	.005
4 (b)	7.9	2.875	3.92	2.409	6.897	.033
6 (a)	7.47	3.62	5.028	2.598	4.302	.000
6 (b)	6.82	3.20	3.587	2.544	5.214	.036
9	5.46	4.89	3.14	1.89	1.18	.118
12	5.82	1.60	4.284	2.023	5.640	.000
13	4.35	2.07	2.547	1.859	4.562	.008
14	6.12	2.20	4.008	1.814	5.643	.002

insignificant (Hu & Adey, 2002; Sen & Mukhopadhyay, 2011; Sharma & Shukla, 1971).Convergent items were analyzed with the help of their facility value and discrimination index. The following table (Table 3) showing the result.

Table 4: F.V. and D.I. of convergent Type Items (N= 800)

Item No.	R_U	R_L	F.V. (%)	DI.	Remarks
3 (a)	50	19	69	0.62	Accepted
3 (b)	51	42	80	0.16	Rejected
3 (c)	42	35	67	0.12	Rejected
5 (a)	36	23	59	0.26	Accepted
5 (b)	19	4	20	0.26	Rejected
5 (c)	43	26	69	0.30	Accepted
5 (d)	19	4	20	0.26	Rejected
7 (a)	37	23	60	0.30	Accepted
7 (b)	42	15	57	0.54	Accepted
8 (a)	36	17	53	0.38	Accepted
8 (b)	51	42	80	0.16	Rejected
10 (a)	45	32	77	0.26	Accepted
10 (b)	47	41	88	0.12	Rejected
11 (a)	36	21	50	0.26	Accepted
11 (b)	47	41	88	0.12	Accepted
11 (c)	26	13	39	0.26	Accepted
11 (d)	36	21	50	0.26	Accepted
11 (e)	38	16	54	0.40	Accepted
11 (f)	40	13	46	0.47	Accepted
11 (g)	19	4	20	0.26	Rejected
11 (h)	43	31	74	0.24	Accepted
11 (i)	49	39	77	0.17	Rejected
11 (j)	19	4	20	0.26	Rejected
11 (k)	38	14	52	0.48	Accepted
15 (a)	43	18	61	0.50	Accepted
15 (b)	40	15	55	0.50	Accepted
15 (c)	42	36	68	0.10	Rejected
16	50	19	69	0.62	Accepted
17	49	16	65	0.70	Accepted
18	45	11	56	0.68	Accepted
19 (a)	42	10	52	0.64	Accepted
19 (b)	43	10	53	0.66	Accepted
20 (a)	31	10	41	0.42	Accepted
20 (b)	43	10	52	0.66	Accepted
20 (c)	31	10	41	0.42	Accepted

After item analysis the final version of the Mathematical creativity test consisting following items

Table 5: All the Final Items

Sl. No.	Types	SI- Factor	Number of Suitable Items	Maximum time in minute
1.	Number Attributes (Divergent)	DMS	2 (Item No. 1 (a) ,(b))	8
2.	Finding Similarities (Divergent)	CMT	2 (Item No.2 (a) , (c))	10
3.	Figural Implication (Convergent)	NFI	1(Item No. 3 (a))	3
4.	Combination (Divergent)	DFT	2 (Item No. 4 (a), (b))	10
5.	Correct Location (Convergent)	CFI	2 (Item No. 5 (a) ,(c))	3

6.	Multiple uses (Divergent)	DMC	2 (Item. 6 (a) (b))	10
7.	Special Perception (Convergent)	NFT	2 (Item No. 7(a), (b))	3
8.	Finding Analogy (Convergent)	CMR	1 (Item No. 8 (a))	2
9.	Finding Correct relationship (Convergent.)	EMR	1 (Item No. 10 (a))	2
10.	Finding opposite word (Convergent)	NMR	7(Item No. 11 (a,c,b,e,f,h,k))	7
11.	Predicting Consequences (Divergent)	NFT	1 (Item No.12)	7
12.	Spatial visualisation(Divergent)	CFT	1 (Item No. 13)	7
13.	Constructing associated figures (Divergent)	DFT	1 (Item No. 14)	7
14.	Figural Subtraction (Convergent)	ESR	2 (Item No. 15 (a) (b))	1
15.	Figural Analogy (Convergent)	CFR	1(Item No. 16(a) (b)))	1
16.	Figural Exclusion (Convergent)	CFC	1 (Item No. 17)	2
17.	Judging Mathematical expression (Convergent)	ESR	1 (Item No. 18, 20)	2
18.	Form Figural Reasoning (Convergent)	ESR	1 (Item No. 19(a))	2
Total			33	90 minutes

Items belongs to different part of the final test such as , Number Attributes, being considered as a single one as shown in the above table (Table 5) ,(i,e. item 1(a) and 1(b) were considered as a single one as item no. 1 and so on).

Reliability of the test:

Internal Consistency Reliability:-

The present test for testing Mathematical creativity consists of two main types of items,

(i) Items based on divergent thinking

(ii) Items based on convergent thinking.

The scoring procedure adopted for these two types of items are different in nature.

In this field researcher decided to adopt different methods to determine internal consistency of these two types of items.

(i) K-R_{20} is used to compute the reliability coefficient for all convergent items used in this test as they are dichotomous in nature (two-point scoring). As the K-R_{20} formula demands to have a item analysis worksheet ready before hand to verify whether items vary much in their indices of difficulty or not, so researcher decided to use this method to determine items homogeneity after preparing item analysis and get this method suitable for this purpose.

(ii) Coefficient alpha formula is used to compute Internal consistency reliability of the divergent part of the test. For calculating reliability of test which receives different numerical scores on an item, formula 'α' has been formulated (Cronbach, 1951; Kaiser and Micheal, 1975).

The same formula was used for estimating internal consistency reliability for entire test.

Table 6: Coefficient of Internal consistency Reliability(800)

Test (Part / Entire)	**'r' or '$\alpha'(r_{tt})$**
i. Convergent Part	KR_{20} = 0.8276**
ii. Divergent Part	r_{tt}= 0.73**
iii. Entire test	r_{tt}= 0.74**

** - Significant at 0.01 level

The above table shows satisfactory internal consistency of the test .

Inter - Scorer Reliability:-

The estimating Inter-scorer Reliability responses of 800 students of sample were evaluated and scored independently by two examiners. One of them was researcher herself and another one is a teacher of a reputed H.S. School in Kolkata, who scored using the scoring key provided by the researcher as per the instruction given in the question paper.

Coefficient of correlation (using Product Moment method) between these two set of scores were found to vary between 0.75 to 0.95 for the divergent items, indicating +ve high correlation, and to be +0.98 for each of the convergent items indicating highly reliable procedure of scoring. Hence the inter scorer reliability of the test is high.

Validity of the test:

Face validity:

To check what this test appears to measure, 30 mathematics teachers working in different H.S. schools and Secondary schools of West Bengal were asked the following questions:

i) Which items in the test are appropriate to measure mathematical creativity of the students who have completed the syllabus of class IX and X?

ii) Which items in the test are not appropriate to measure the same for the same group of students?

Table 8 : Teachers' opinion towards appropriateness of the items (N=800).

Items No.	Teachers' Opinion		Chi-square (χ^2)	level of significance
	Appropriate	Not appropriate		
1(a)	25	5	6.67	0.01
1 (b)	25	5	13.34	0.01
2(a)	22	8	6.54	0.02
2(b)	24	6	10.80	0.01
3	24	6	10.80	0.01
4(a)	28	2	22.54	0.01
4(b)	27	3	19.20	0.01
5(a)	28	2	22.54	0.01
5(b)	28	2	22.54	0.01
6(a)	27	3	19.20	0.01
6(b)	27	3	19.20	0.01
7(a)	22	8	6.54	0.02
7(b)	25	5	13.34	0.01
8	24	6	10.80	0.01
10	22	8	6.54	0.02
11(a)	21	9	4.80	0.05
11(b)	21	9	4.80	0.05
11(c)	21	9	4.80	0.05
11(d)	22	8	6.54	0.02
11(e)	22	8	6.54	0.02
11(f)	22	8	6.54	0.02
11(g)	22	8	6.54	0.02
12	23	7	6.54	0.02
13	24	6	10.80	0.01
14	23	7	6.54	0.02
15(a)	22	8	6.54	0.02
15(b)	21	9	4.80	0.05
16	22	8	6.54	0.02
17	21	9	4.80	0.05
18	24	6	10.80	0.01
19	28	2	22.54	0.01
20(a)	27	3	19.20	0.01
20(b)	22	8	6.54	0.02

The result shown in the above table indicate favourable opinion of the subject teacher of different schools towards the test items. This can be an explanation for satisfactory face validity of the test.

Content Validity or Intrinsic Validity:

In order to measure the intrinsic validity of this test researcher tried to find out item-item correlation and item -total correlation separately for two set (convergent type and divergent type) of items using Person Product Moment method.

As per the values of coefficient of correlation between different items varies from moderate to high values and is considerably high in most of the cases. Most of the coefficients are significant at 0.01 level & some are significant at 0.05 levels. This indicating satisfied intrinsic validity of the test.

Content Validity:

Here same experts ,who considered for face validity rated the items and the entire test with 5-point rating scale on the basis of different sets of questions, which are related to the (i) appropriateness of the concepts of mathematics as per the level of understanding of the target group for individual item, (ii) suitability of selection of each item as per Mathematical creativity of secondary level students, (iii) adequacy in inclusion of all the essential concepts in mathematics appears to useful for the target group, (iv) appropriateness of all included abilities in the test to measure mathematical creativity of the target group etc. Average rating of experts for each items and entire tests in respect of its content validity measurement is found to be highly satisfactory.

Predictive Validity:

From this point of consideration, predictive validity of the present test was determined by correlating the scores of the entire sample in the test of Aptitude in mathematics constructed and standardised by the present researcher. Using Pearson product moment method the coefficient of correlation between two set of scores was found to be 0.89 which is significant at 0.01 level and found to be highly satisfactory.

To predict aptitude in mathematics accurately a regression equation had also been established by the researcher which is as follows:

$Y = 0.32 X + 25.91$; Standard error estimated = 5.312

X = scores on mathematical creativity and Y = Scores on Aptitude in mathematics.

Construct Validity:

Factorial validity should be an important form of construct validity and it should be the first step in validating a creativity test (Guildord, 1950). As with most SPSS procedures there is a lot of output generated. Here researcher has gone through the key pieces of information that are needed to interpret the result of PCA.

The 33 convergent and divergent items of the Mathematical creativity test were subjected to principal component analysis (PCA) using SPSS version 12.Initially before using PCA the suitability of data for factor analysis was assessed. As the many coefficients of correlation matrix are of 0.3 and above, the Kaiser- Meyer- Okin value is 0.790, exceeding the recommended value of 0.6 (Kaiser, 1970, 1974) and the Barlett's Test of Sphericity (Bartett, 1954) reached statistical significance, all these are the sign of supporting the factorability of correlation matrix.PCA revealed the presence of five components with eign values exceeding 1(4.975, 1.961, 1.328, 1.250, 1.118) and these five components explain a total of 55.959percent of the variance(using Kaiser's criterion).

An inspection of the scree plot revealed a clear break after the 4rth component. Using Catell's (1966) scree test, it has been decided to retain four components for further investigation. This was further supported by the results of Parallel Analysis (Monte Carlo parallel analysis), which showed only four components with eign values exceeding the corresponding criterion values for a randomly generated data matrix of the same size (i,e. 33 variables X 800 respondents).

Table 11: Comparison of eigenvalues from PCA and the corresponding criterion values obtained

Component Number	Actual Eigenvalue from PCA	Criterion value from parallel analysis		Decision
		Monte Carlo parallel analysis	SPSS parallel analysis (O'Connor, B. P. (2000))	

1	4.975	1.2752	1.2780	Accepted
2	1.961	1.2310	1.2280	Accepted
3	1.328	1.1915	1.1897	Accepted
4	1.250	1.1553	1.1554	Accepted
5	1.118	1.1232	1.1251	Rejected

Now for interpretation of these four components, Varimax rotation was performed. The rotated solution revealed the presence of simple structure (Thurston, 1947), with all the four components showing a number of strong loadings.

Table 12: Pattern Matrix

	Component			
	1	**2**	**3**	**4**
div.14	.793			
div.1	.750			
div.4	.676			
div.6	.667			
div.2	.660			.344
div.12	.619			.327
div.13	.482	.317		
con.18		.800		
con.17		.683		
con.20		.668		
con.19		.312		
con.5			-.744	
con.7			-.657	.318
con.8			-.616	
con.11		.387	-.532	
con.3			-.357	
con.16				.747
con.15		.477		.533
con.10				.316

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

These four components solution explained a total of 50.073% of variance with four component respectively 26.184%, 10.323%, 6.988% and 6.578 %.

The total variance (50.073%) did not change after rotation and distributed among 4 components. By looking at the highest loading variables on each of the component, researcher tried to identify the nature of the underlying latent variable represented by each component and labelling 4 components as shown below:

Table 13: Labelling of the components and PCA for Mathematical Creativity

Component	Items (identification of component)	Labelling of the components	% of Variance
1	1,2,4,6,12,13,14	Mathematical Divergent Production Ability	26.184%
2	15,17,18,20	Evaluation of Symbolic Transformation Ability in Mathematics	10.323%
3	5,7,8,11	Cognition of Figural/Symbolic Implication in mathematics Ability	6.988%
4	15,16	Memory for Mathematical Figural Relation Ability	6.578%
			Total variance - 50.073%

The Component Correlation Matrix showing that the strength of relation between four factors are quite low but some of them are greater than 0.3 as shown below.

Table 14: Component Correlation Matrix

Component	1	2	3	4
1. Mathematical Divergent Production Ability	1.000	.269	-.220	.073
2. Evaluation of Symbolic Transformation Ability in Mathematics		1.000	-.310	.165
3.Cognition of Figural/Symbolic Implication in mathematics Ability			1.000	-.140
4.Memory for Mathematical Figural Relation Ability				1.000

This suggests that the test has sound construct validity and , these all four variables together are constructed "Mathematical Creativity Test".

Norms of the test:

An individual performance in any psychological and educational test recorded in terms of the raw scores. In absence of any standard norm all these raw scores convey no meaning in themselves. Here also for interpretation of the raw scores on mathematical creativity test, four norms have been suggested by the present researcher as given below.

Norm of the test on Mathematical Creativity:

1. Simply to express scores of entire test in terms of mean and S.D. of the responses of entire sample.
2. Percentile Norm of the same sample.
3. Normalised score norm
4. Stanine norm of the same sample.

Table 17 :Mean and Standard Deviation of the Test(N= 800)

Test	Mean	S.D
Mathematical Creativity	84.298~ 84	33.242~33

Table 18 :Stanine Norm of the Test

Stanine Scale	Raw Score	Normalised Score Norm	Percentile Norm	Interpretation
9	178 and Above	0.79 and Above	P_{96}-Above	High
8	117 - 177	0.46 -0.79	P_{89} - P_{96}	Above Average
7	103 - 116	0.39 -0.46	P_{77} - P_{89}	
6	86 - 102	0.30 – 0.39	P_{60} - P_{77}	Average
5	74 - 85	0.25 -0.30	P_{40} - P_{60}	
4	61 - 73	0.17 – 0.23	P_{23} - P_{40}	
3	52 – 60	0.12 – 0.17	P_{11} - P_{23}	Below

2	39 - 51	0.05 -0.12	P_4 - P_{11}	Average
1	Below 38	Below 0.05	Below P_4	Low

Implication:

The implication acquired from this research is as follows.

1. In identifying mathematically creative child.
2. To understand the student's level of creativity in Mathematics.
3. In educational and vocational guidance and counseling services.
4. To plan for nurturing student's mathematical creative talent and choose proper methods/teaching strategies/technologies for this purpose.
5. In future maturation of field of creativity as well as mathematical creativity.

All these can help educators to nurture student creativity. Hence the present study.

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