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Development of a Mathematical Creativity Test for Bengali Medium School Students[1]

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Based on the work of Haylock (*cf.* [Haylock, D. W. (1987). A framework for assessing mathematical creativity in schoolchildren. *Educ. Stud. Math.* **18(1)**, 59–74]) a mathematical creativity test containing items of two categories overcoming fixation and divergent thinking has been developed for Bengali medium school students with sample size 262. The items measuring divergent thinking are found highly internally consistent and there is a significant correlation between overcoming fixation and divergent thinking. Study of the factorial validity of the test by Thursstone's centroid method gives satisfactory result. Validity coefficient of the test with teachers' rating, alpha reliability and test-retest reliability of the test are also found satisfactory.

Keywords: divergent thinking, mathematical creativity, overcoming fixation, reliability, validity
MESC Classification: C30, D60
MSC2010 Classification: 97C30, 97D50

1. BACKGROUND

Pehkonen (1997) stated that creativity is not a characteristic only found in artists and scientists, but it is also a part of everyday life. Tammadge (1979) suggested that there is an urgent need for mathematics teachers to identify, encourage and improve creative mathematics ability at all levels. According to Sriraman (2004) "it is in the best interest of the field of mathematics education that we identify and nurture creative talent in the mathematics classroom."

Mathematical creativity is a topic of discussion of many mathematicians and mathe-

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matics educators but there is no single clear universally accepted definition of it. According to Barbeau (1985) creativity in mathematics ranges from a neat twist in solving a problem to the erection of a complex theoretical edifice. Sriraman (2004) defined mathematical creativity as the process that results in unusual and insightful solutions to a given problem, irrespective of the level of complexity. Singh (1990) defined that mathematical creativity is the ability to produce original and unusual applicable methods and solutions to problems. Production of unusual, original and insightful solutions to problems is important to exhibit creative ability in mathematics. It demands a turn in thinking into an unconventional way for an original solution.

In school mathematics education to promote mathematical creativity a teacher has to identify students with this ability and he also has to search the way to foster it. Silver (1997) argued that inquiry-oriented mathematics instruction, which includes problem-solving and problem-posing tasks and activities, can assist students to develop more creative approaches to mathematics. Through the use of such tasks and activities, teachers can increase their students' capacity with respect to the core dimensions of creativity; namely, fluency, flexibility, and novelty.

To measure creative ability in mathematics Balka (1974) suggested six criteria two of which were convergent and four were divergent. Evans (1964; as cited in Imai, 2000) developed some problems to measure divergent thinking in mathematics and its method of evaluation. He identified three aspects of divergent thinking in mathematics: fluency, flexibility and originality. Singh (1987) developed a test to measure mathematical creativity of students at the middle-class stage. In his test, tasks pertaining to fluency, flexibility, originality and elaboration had been used in the construction of the test. Alongside measuring divergent thinking ability Haylock (1987) argued for another aspect, overcoming fixation to assess students' creativity in mathematics. In an investigation Imai (2000) found that those students who can overcome fixation in mathematics can make varied and original ideas in open-ended situations in mathematics. Most of the tests to measure creativity do not contain items that measure students' ability to overcome fixation.

Against this background the present study was aimed to develop a mathematical creativity test containing items both of the categories overcoming fixation and divergent thinking, which fit culturally and educationally to Bengali medium school students of India.

2. FRAMEWORK OF THE TEST

The theoretical basis of construction of the test of present study is the work of Haylock (1987), "A Framework for Assessing Mathematical Creativity in Schoolchildren," where two key aspects were argued important to assess mathematical creativity of a child. These are *overcoming fixation* and *divergent thinking.*

2.1 Overcoming Fixation

Much considered four stages of one's creative process of thinking are preparation, incubation, illumination and verification. In the preparation stage a problem is investigated thoroughly and consciously. In this stage, required information about the problem is gathered. In the incubation stage the problem is put aside and the subconscious mind begins to process the information. The transition from incubation to a sudden even unexpected insight for a solution of the problem to the conscious mind is called illumination. The verification stage is the work of conscious mind to verify the insight for a solution of the problem and put it down in a form to communicate with others. Haylock (1987) suggested that children fail at the time of doing mathematics to transit from the incubation stage to illumination because of mental set or fixation, which resists creative thinking.

> Much of the interest in the creative process lies in the transition from the incubation stage to illumination. Why is it that sometimes the insight does not occur? One suggestion which seems particularly relevant to children doing mathematics is that the insight fails to take place because the person concerned is subject to a mental set. .... Fixation in problem-solving is the counterpart to flexibility, a key aspect of creative thinking. (Haylock. 1987. p. 64)

According to Krutetskii (1976; as cited in Haylock, 1987) "flexibility of mental processes" is an important component of mathematical ability in schoolchildren. This flexibility is shown, for example, by the overcoming of fixations, sometimes referred to as 'self-restrictions', or the breaking away from a stereotyped method of solution. Balka's (1974) third criterion for measuring creative ability in mathematics was "the ability to break from established mind sets to obtain solutions in a mathematical situation".

Alongside these Haylock reviewed a number of literatures and concluded that overcoming fixation is key aspect of mathematical creativity to the children doing mathematics in school. Two key ideas emerged most relevant to fixation, *content universe fixation* and *algorithmic fixation.*

Content universe fixation: In the process of solving a problem sometimes pupils restrict themselves within a narrow part of the content universe of the problem. They may restrict inappropriately or unnecessarily the range of elements which may be used or related to a problem. This is known as content universe fixation.

Algorithmic fixation: A pupil may show fixation in mathematics by the continued use of an initially successful algorithm even when this becomes inappropriate or less than optimal. This is known as algorithm fixation.

2.2 Divergent Thinking

To measure creativity, Guilford, Torrance and many other test developers measured the ability to produce divergent products. In a divergent production test a problem with many solutions is given to the subjects and they asked to produce many, varied and original solutions and the responses are assessed, by measuring fluency (the number of correct responses), flexibility (the number of categories of the responses) and originality (the statistical infrequency of the responses).

Haylock reviewed a number of literatures and decided ability of divergent production in a mathematical situation as an aspect of mathematical creativity. To assess mathematical creativity on the notion of divergent thinking he found three approaches most relevant. These are *problem solving, problem posing* and *redefinition.*

Problem solving: In this task a student is given a mathematical problem with many solutions and asked to produce many, varied and original responses.

Problem posing: In this task a student is given a paragraph containing some numerical information and then asked to write down many questions which could be answered using the given information.

Redefinition: In this task students are given a mathematical situation and they are required to response in such a way so that the students are forced to redefine the elements of the mathematical situation in many, varied and original ways.

3. ITEM SELECTION

To measure ability to overcome fixation and divergent thinking ability, such items were chosen so that students of every level can express their abilities. Students were given enough time to think in different mathematical situations and put down their responses. Pupils were inspired to give original responses. Selected items for the mathematical creativity test are given bellow.

I. **Content universe fixation:** Find numbers that multiplied by 2 produce numbers less than 10.

II. **Algorithmic fixation:** Suppose you have to pay some money to your friend. You and your friend have some money with yourselves. What is the way to pay? The first problem is solved. You have to solve rest six problems. The problems are given in table 1.

Table 1. Sequence of problems to assess algorithmic fixation.

	You have to pay (Rs.)	Notes with you (Rs.)	Note with your friend (Rs.)	Answer
1	33	20, 10, 5	2	20+10+5-2=33
2	16	10, 5, 2	1	
3	17	10, 10, 2	5	
4	28	20, 5, 5	2	
5	16	20, 5, 1	10	
6	6	5, 2, 1	2	
7	100	100, 50, 50	100	

III. **Problem solving:** Find the subsets of {5,6,7,8,9,10,11,12,13,14,15} having some particular properties and give a name of each of the subset.

IV. **Problem posing:** A rectangular garden of length 10 meter and width 6 meter has a path of width 2 meter along the length of the garden. Cost to fence each meter is rupees 20.

Write down questions, which could be answered using the given information.

V. **Redefinition:** Find the similarities between 14 and 24.

For each of the three sub-tests measuring divergent thinking (last three items) an example was given to make familiar students with the respective task and the students were required to produce many, varied and original responses.

4. RATIONAL FOR THE ITEMS INCLUDED IN THE TEST

Item-I (Content universe Fixation): At the time of responding this problem large no of students fixate their thinking within a narrow domain which results positive integers as answers. Those who overcome self-restriction regarding the content universe of the problem, search for answers beyond the domain of positive integers. Therefore this item examines the ability to break mindset for a wider range of content universe of the problem.

Item-II (Algorithmic Fixation): In this item a successful algorithm is established in the students' mind in the initial problem and after then a series of similar problems are given to solve. The students, who have the ability to break inertia of mindset, overcome the established algorithmic fixation at the time of responding last two problems of the series. Therefore this item examines the ability to break algorithmic fixation.

Item-III (Problem Solving): While responding the problem of this item, pupils' thinking should be flexible enough to produce many, varied and remote answers which could be assessed for fluency, flexibility and originality. Thus this item examines divergent thinking ability of pupils.

Item-IV (Problem Posing): While responding this problem, pupils have opportunity to think in a varied way to produce original responses, which could be assessed for fluency, flexibility and originality. Thus this item examines divergent thinking ability of pupils.

Item-V (Redefinition): To find the similarities between 14 and 24 pupils are to redefine the numbers again and again and their thinking should be flexible enough to produce many, varied and original responses. Thus this item examines divergent thinking ability of pupils.

5. SAMPLE

A sample of 262 Bengali medium students studying in classes of Grades 7 and 8 was taken from two urban and two rural schools (134 boys and 128 girls).

6. SCORING

Item-I

i) Score for response 0.
ii) Score for negative integers.
iii) Score for positive rational numbers (excluding integers) less than 5.
iv) Score for negative rational numbers (excluding integers).
v) Score for positive irrational numbers less than 5.
vi) Score for negative irrational numbers.

Item-II

i) Score for response, 5+1 = 6 for the 6th problem.
ii) Score for each of responses 100 and 50+50 = 100 for the 7th problem.

Raw scores of all the students in each item-I and item-II were transformed into T-scores with a mean of 50 and SD 10. T-scores were considered as the scores of the respective items.

Item-III, Item-IV, and Item-V: For each of item-III, item-IV, and item-V, fluency, flexibility and originality of the responses were computed. Raw scores of fluency, flexibility and originality of an item were transformed into T-scores with a mean of 50 and SD 10. One third of the total of three T-scores was considered as the score of the respective item.

Total of the scores of the five items was considered as the total mathematical creativity score.

7. VALIDITY AND RELIABILITY

7.1. Acceptance of the Items Measuring Divergent Thinking

To measure internal consistency among the items (last three items), which measure ability to think divergently, the item scores of problem solving, problem posing and redefinition were correlated with the total score of those three items. Correlation of each of the three items with the sum of other two items was also calculated. Correlation matrix for total fluency, total flexibility, total originality and the total of the three was also calculated. The results are given below in Table 2 and Table 3 respectively.

Table 2. Coefficients of correlation of the items III, IV, and V with the total of the three and with the total of the rest two items ($N = 262$)

Items	Correlation with total score of the three items	Correlation with the sum of score of rest two items
III. Problem solving	0.761	0.473
IV. Problem posing	0.795	0.544
V. Redefinition	0.840	0.597

Note: All the correlations are significant at the 0.01 level.

Table 3. Coefficients of Correlation Among Fluency, Flexibility, Originality and Total of the Items III, IV and V (N=262)

	Fluency	Flexibility	Originality	Total
Fluency	-			
Flexibility	0.873	-		
Originality	0.633	0.578	-	
Total	0.937	0.916	0.824	-

Note: All the correlations are significant at the 0.01 level.

The correlations in Table 2 indicate that the items III, IV and V are highly internally consistent. Also the correlations in Table 3 show a significantly high degree of relationship among different dimensions of divergent thinking.

7.2. Relationship between Overcoming Fixation and Divergent Thinking

To find relationship between overcoming fixation and divergent thinking, correlation coefficients between items of the category overcoming fixation with total score of the category divergent thinking were calculated. Conversely correlation coefficients between items of the category divergent thinking with total score of the category overcoming fixation were calculated. The results are given in Table 4 and Table 5.

Table 4. Coefficients of correlation of items of the category overcoming fixation with the total score of the category divergent thinking ($N = 262$)

Items	Total of the category divergent thinking
I. Content universe fixation	0.404
II. Algorithmic fixation	0.394
Total score on fixation	0.520

Note: All the correlations are significant at the 0.01 level.

Table 5. Coefficients of correlation of items of the category divergent thinking with the total score of the category overcoming fixation ($N = 262$)

Items	Total of the category overcoming fixation
III. Problem solving	0.398
IV. Problem posing	0.464
V. Redefinition	0.389
Total score on divergent thinking	0.520

Note: All the correlations are significant at the 0.01 level.

The correlation coefficients in Table 4 and Table 5 show that the two categories overcoming fixation and divergent thinking are significantly related. Imai (2000) also found after an investigation that, overcoming fixation relates to flexibility and originality of divergent thinking.

7.3. Factorial Validity of the Test

To study the factorial validity of the test, Thurstone's centroid method (*cf.* Thurstone, 1934) was applied on the entire sample. First common factor saturations were calculated. The results are given in table 6.

Table 6. Factorial Validity (N=262)

Items	First common factor by Thurstone's centroid method	Rank order of the items
I. Content universe fixation	0.511	4
II. Algorithmic fixation	0.500	5
III. Problem solving	0.620	3
IV. Problem posing	0.714	1
V. Redefinition	0.700	2

The results of Table 6 show that the five items are explained to some satisfactory extent by one common factor. Though two different aspects of mathematical creativity are used in this test, the result is not unexpected because it has been found in Table 4 and Table 5 that the two aspects are correlated significantly.

7.4. Validity Coefficient with Teachers' Rating

To get the validity coefficient with teachers' rating, a sample of 132 students was taken and total creativity score was correlated with the rating of teachers, who were in close contact with their students. A substantial coefficient of correlation 0.670 was found with significant at the 0.01 level.

7.5. Item Rest of Test Correlations and Alpha Reliability

Item rest of test correlations is given in Table 7. The following alpha coefficient of reliability recorded by the present test was 0.716, which exceeded the Kline's (1993) criterion of 0.7.

Table 7. Item Rest of Test Correlations (N=262)

Items	Correlation
I. Content universe fixation	0.385
II. Algorithmic fixation	0.376
III. Problem solving	0.505
IV. Problem posing	0.588
V. Redefinition	0.559

Note: All the correlations are significant at the 0.01 level.

7.6. Test-retest Reliability

To find test-retest reliability, 39 students studying in class Grade 8 were retested after a time period of five weeks. Test-retest reliability was found 0.868, which is highly satisfactory.

8. CONCLUSION

The degree of validity and reliability coefficients presented above, are high enough to conclude that the present test is a valid and reliable test. Therefore the test is safe enough to use it in research work and educational purpose.

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