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# Measurement of Creativity in Physics - A Brief Review on Related Tools

Dr. Rajib Mukhopadhyay
*Department of Education, St. Xavier's College, Kolkata, West Bengal, India*

**Abstract:** *Suitable tools pave the way for successful accomplishment of objectives of any research program. Selection of tools for a particular study depends mostly on the availability of those tools appropriate for the purpose under consideration. Therefore, for selection of tool, it is necessary to survey the available tools to judge their suitability for the study in terms of their efficacy, coverage of variables and sample etc. Hence is the importance of review on tools in research.*

*In the present context of revolution of science and technology, to foster creativity in science education has become one of the needs of the hour. It is important particularly in the context of science learning of school students. Among various disciplines of science, physics has scope enough to nurture creativity in its own domain which indicates the possibility of nurturing creativity in the context of learning physics. This nurturance is necessary for utilizing human resource.*

*Identification precedes nurturance. So identification of creative talents in physics employing suitable tool on creativity in physics is important equally, which also suggests importance of selection of appropriate tool on Creativity in Physics. Under this circumstance, reviewing tools of the same has become a major concern of science educators. This also leads to selection of the present study.*

*The study has explained need of investigating creativity in learning, in the context of a specific domain, particularly in the context of learning physics. Scientific creativity is the broader domain of the study. Therefore, the study has discussed the operational construct of both scientific creativity and creativity in physics, as viewed by different researchers. Existing tools on both these two (particularly that of creativity in physics) have been reviewed in details highlighting the categories of items selected, the target sample group selected, criterion of scoring technique used, and various other psychometric considerations including different aspects of their reliability and validity. Areas of further development have also been suggested. The study has its significance to the researchers in selecting or constructing tools and also to the teachers in identifying creative talent in physic selecting suitable tool and subsequently administering.*

***Key words**: Tool review, Creativity in Physics, Scientific Creativity, Psychometric Consideration.*

## I. Introduction

Creativity has scope enough to be investigated in the context of learning (Mukhopadhyay, 2011). Even Guilford, one of the pioneers in the field of scientific research on creativity has emphasized on this particular aspect of creativity (Baghetto, 2008). But, in spite of this, much of the researches on creativity of the past half century have studied creativity of eminent persons, far less have studied the role that creativity plays in students' learning (Plucker, 2006). Not only that, earlier researches have considered creativity, in general. For example, creativity has been conceptualized as an ability or characteristics of the person (Barron,1988; Taylor,1988) or as a cognitive process (Boden,1992; Schank,1988; Wiesberg, 1986) influenced by thinking style and personality traits (Richardson and Crichlow,1995; Sternberg, 1988) (in Diakidoy & Constantinou, 2001), and associated with divergent thinking (Guilford,1950; Torrance,1988). Questions arise in this context are- if creativity is to be studied in the context of learning, specifically in institution, what are the major concerns of researches? Whether researches on creativity in general, and creativity in learning resemble similarities in every respect?

In institution, creativity is considered in relation to a specific context, a definite task, a problem, an academic domain of knowledge etc. In this situation, domain or context specific studies on creativity are important (Diakidoy & Constantinou, 2001). Feldhusen (1994) suggested that creative functioning in one domain may be unique and psychologically different from that of in other domain. Alexander (1992) and Amabile (1987) hence emphasized the need for specific domain or discipline- based knowledge and skills for fostering creative thinking. Other researchers (Albert,1983; Feldman,1986; Gardner,1983) also concluded that creativity is domain specific. Morten & Vanesa (2007) pointed out that each individual subject should emphasize on creativity within an agenda reflecting characteristics of each. This is why domain-specific creativity is gradually drawing more and more attention of researchers. This domain specificity might be the feature of learning related creativity. This trend also influences the psychometric research works on creativity, particularly the construction of various tools in association.

In the context of learning science particularly, need of investigating creativity is felt by science educators. Science learning resembles a number of similarities with creative process (Meador, 2003); various steps of scientific process (namely identifying problems, analyzing those, expressing scientifically, formulating multiple hypotheses in search of solution, verification of those step-wise either by analytical thinking or suitable experiments etc.) are essentially also that of a creative process (Aktamis & Ergin, 2008). Not only that, this is also relevant in the modern context of scientific, as well as the complex society which needs scientifically tempered and skilled persons having creative vision.

The emerging trend of context or domain specific research on creativity in the context of learning, and the felt need of investigating creativity in science education leads science educators to consider studying creativity in scientific context separately, where knowledge of creativity, in general, is found to be inadequate ( Mukhopadhyay,2011). Creativity in science education, to be called precisely as **scientific creativity** thus has emerged as an independent field of research.

Physics is one of those science subjects which has immense utilitarian, cultural and intellectual values. The subject itself has a number of potentialities within its own domain to foster creative thinking. Hence identification and subsequent nurturance of creative talent in physics education is important.

Review of tools is an important aspect of research activity leading to the selection/construction of a suitable device for collecting research data indicating need of reviewing tools on scientific creativity in general, and tools on creativity in physics, in particular. Explanation of various psychometric aspects of the associated constructs seems also meaningful to be considered for this purpose. These two are the major concerns of the present study, which are discussed step by step as follows.

## II. Explanation Of Psychometric Aspects Of Scientific Creativity And Creativity In Physics

Idea of Guilford (1956) on creativity influenced the research works on scientific creativity to a great extent. Majumdar (1974), Singh (1981), Misra (1986), Sharma and Sukla (1986), Hu and Adey (2002) etc. have investigated scientific creativity in this light. Majumdar (1974) and Singh (1981) explained scientific creativity in relation to the SI model proposed by Guilford (1956). Divergent production, along with some other intellectual operations as convergent production, cognition and evaluation are considered to explain the construct of scientific creativity by these researchers. Misra (1986) explained scientific creativity in the light of Guilford (1956); considered it in relation to divergent thinking only.

Hu and Adey (2002), being influenced by Guilford (1956), explained scientific creativity in relation to a three dimensional structure model – ‘Scientific Structure Creativity Model’ (SSCM), having the dimensions as following:

i) Scientific process (scientific thinking and scientific imagination)
ii) Personality trait (fluency, flexibility, originality).
iii) Scientific product (technical product, scientific knowledge, scientific phenomenon, scientific problem).

Scientific creativity, according to Hu and Adey (2002) is “a kind of intellectual trait or ability producing a certain product that is original and has social or personal value, designed with a certain purpose in mind, using given information” (page.- 391).

Creativity in physics is the specific area of scientific creativity which is the focal theme of present study. Overall features of scientific creativity (discussed already) are also the basic features of creativity in physics. But at the same time, it also has some special features which are related to knowledge and understanding of various concepts in physics particularly.

In the context of learning, creativity in physics is explained as a multidimensional and very complex intellectual process associated with knowing, understanding and applying different concepts, laws, principles, theories, formulae, symbols etc. used in physics; which help a learner in recognizing a problem guessing the probable causes, formulating the problem identifying variables (figural, symbolic, semantic), relating those (constructing equations or using semantic relationship), finding probable solutions using analytical thinking, anticipative imagination (anticipating probable consequences) and subsequent experimental verification whenever necessary. All these develop foresight of learners in planning, their abilities in finding new relationships among the conventional objects and similarities between apparently dissimilar concepts, in elaborating a concept, finding various word-associations with different scientific terms, using correct language in physics, in correlating various concepts and also the ability of improving quality of scientific products encouraging divergent thinking in general, and also convergent thinking, in particular. This ultimately leads to verification of probable solutions of the problem by accepting or rejecting those step wise (Mukhopadhyay, 2011).

## III. Tools Of Scientific Creativity, And Creativity In Physics

Important features of some available tools on Scientific Creativity are shown in the following table (Table 1).

**Table 1 : Tools on Scientific Creativity**

| Test | Sample | Sub dimensions | Scoring Criterion | Reliability | Validity |
|---|---|---|---|---|---|
| **1.**Majumdar's Scientific Creativity Test (Majumdar, 1974) | Secondary Higher Secondary and Graduates | Both convergent and divergent abilities w.r.t different S.I. abilities (Guilford, 1956) [eg. Remote association, Figural Redefinition, Conceptual correlates, Perceptual foresight etc.] | (1) Fluency, Flexibility, Originality and Elaboration for divergent item.<br>(2) Two point scoring (1, 0) for convergent items. | 1.Split–half (r=0.57 to 0.76)<br>2.Inter-scorer (r=0.89 to 0.95) | 1.Construct<br>2.Content<br>3.Predictive (All found satisfactory) |
| **2.**Scientific Creativity Test (Singh, 1981) | Class X | In the same light of Majumdar (1974) | Same as above | 1.Test-retest<br>2.Split–Half (r=0.79 to 0.77) | 1.Content (Satisfactory)<br>2.Convergent (r = 0.46 to 0.78,significant) |
| **3.**Scientific Creativity Test (Misra, 1986) | XI, XII | (All divergent)<br>1.Consequence<br>2.Guess cause<br>3.Unusual use<br>4.Inquisitiveness<br>5.Product improvement<br>6.Block design | Fluency, Flexibility, Originality, Inquisitiveness | 1.Split – half<br>2. Parallel form (r=0.53 to 0.78) | 1.Criterion Validity (t= 2.34, 2.44)<br>2.Intrinsic(r= 0.603 to 0.82 for item-total) |
| **4.** Test on Scientific Creativity (Hu and Adey, 2002) | Secondary student | Different dimensions of S.S.C.M., i.e process, product, trait (all divergent) (e.g.- unusual use, science imagination, product Improvement, problem solving, creative experimental ability etc.) | Fluency, Flexibility, Originality | 1.Internal consistency (a = 0.895)<br>2.Inter-scorer (r = 0.875) | 1.Intrinsic (significant, for item- item, item-Total correlation<br>2.Construct (one-factor structure, explaining 63% variance ) |
| **5**. Test on Scientific Creativity by Sharma and Shukla (1986) | Lower Secondary | Unusual uses, New relation, Just think why (divergent) | Fluency, Flexibility, Originality | 1. Split – half<br>2. Test-retest (significant, both) | 1. Content,<br>2. Predictive |

Review shows the following points:

1. Most of the available tests on Scientific Creativity (except scale no. 1 and 2) have not incorporated convergent items, in spite of relevance of convergent thinking in science learning .
2. Most of the studies are influenced strongly by Guilford (1956)
3. Particularly, test of Majumdar (1974) is widely used, but it is elaborate, exhaustive, may result in fear of boredom and anxiety of learners; a number of items are beyond comprehension of secondary group (Singh, 1981), as well as for higher secondary sample studying in class XI.

Some measures, particularly on Creativity in Physics are discussed as follows:

'Stefan Procopiu Physics Contest' (initiated by group of physics teachers in Romania since 1995, for higher secondary students, in Mukhopadhyay,2011) have emphasized on the process aspect of creativity and discovery learning in relation to creative learning in physics and identified four groups of factors to be considered in this relation. These are –

(a) Scientific Skills (theoretical, experimental, technological, anticipative and imaginative)
(b) Creative Aptitude (sensitivity to problem, fluidity, flexibility, originality, elaboration).
(c) Intellectual Profile (multiple intelligence: logical-mathematical, spatial-visual, naturalistic, musical, body-kinesthetic, intrapersonal and interpersonal).
(d) Intrinsic Motivation (interest, involvement in Physics problems, perseverance, high standard for own result).

The attempt is novel; a comprehensive profile on creativity in physics has been considered, but strong supporting psychometric basis is not found in association.

Diakidoy and Constantinou (2001) measured Creativity in Physics of University students using 3 ill-defined and open-ended problems in physics, considering fluency, originality, appropriateness as criterion. It is the only study found on the measurement of Creativity in Physics. The study is not supported by a strong psychometric basis, as well as has the scope of incorporating convergent items. Therefore a test on Creativity in Physics, for secondary passed students studying in class XI, incorporating divergent as well as convergent items, and having sound psychometric basis is found to be lacking, which may be easily administered in a higher secondary physics class without resulting high fatigue, boredom and anxiety of learners.

Mukhopadhyay (2011) has standardized a Test on Creativity in Physics. The test is constructed for secondary passed students. Science students of class XI studying Physics in different schools in West Bengal were considered as the target population for the present study.

From this population, a group of 212 students was selected as the try out sample. The test was standardized finally on a larger group of 703 students, constituting various components as per gender (boy, girl ), and habitat (urban, semi urban, rural).

In the test, a number of items (14 in total) have been incorporated according to different abilities and factors related with creativity, as well as scientific creativity. Different factors and abilities considered by earlier researchers ( Guilford, 1967; Majumdar, 1974; Singh, 1981; Misra, 1986; Diakidoy & Constantinou, 2001; Hu & Adey, 2002, Sen & Mukhopadhyay, 2009 ) were considered and incorporated with essential modification and innovations. Both the convergent and divergent type items were considered. Types of items incorporated in the test were–planning of circuit, finding analogy, solving figural problem, to establish new relation, equation construction, to find alternate use, to guess consequence, to improve product, sensitivity to problem, word construction, descriptive elaboration, finding similarities, to produce word association, and to conduct scientific experiment. All these fourteen items were grouped into six broad criterion, namely fluency, flexibility, originality, perceptional foresight, conceptual correlates and correct vocabulary. Among these, first three were divergent and the remaining were related to convergent ability. Convergent items have been constructed with special care, though they lead to a single correct response, but while solving those, students have scope enough to utilize the ability of higher order learning skills, as correlating concepts, implementing a theoritical concept in reality etc. With the help of responses obtained from the sample group, an elaborate scoring key was prepared and scoring was done accordingly. Advanced statistical technique based on the theory of normal probability has been utilized for scoring.

Reliability of the test was estimated by considering internal consistency reliability. Cron-bach alpha coefficient of internal consistency for the items related to divergent thinking were estimated. The same were computed for the convergent items using KR-20 formula of coefficient of correlation. Internal consistency reliability for the entire test was also estimated. Inter-scorer reliability was also determined by relating scores of the test given by two different scores.

Face, Intrinsic, predictive, concurrent, criterion, construct and content validity were estimated. Face validity was estimated with reference to teachers' opinion toward the effectiveness of the test. As a measure of intrinsic validity, item-item and item-test correlation were studied. Construct validity was estimated using the technique of factor analysis. Content validity was estimated with reference to the rating of experts. Predictive validity was estimated relating the scores of the test with the scores obtained in the last board examination (standard scores in science) and computing coefficients of correlation. Concurrent validity was estimated relating the scores of the test with the scores of the same group on the Test of Scientific Creativity standardized by Majumdar (1974). Teachers' rating of students' creativity was also considered, with reference to which criterion validity of the test was estimated. Following table (table 2.) shows the detailed results of various aspects of reliability and validity.

**TABLE 2. Reliability and Validity of the test on Creativity in Physics**
**RELIABILITY**

| Reliability | Results |
|---|---|
| 1.Internal consistency reliability, using Cronbach Alpha Coefficient for divergent items, KR – 20 formula for convergent item. | a. alpha (a) = 0.813 ($p<0.01$)<br>b. $r = 0.896$ ($p<0.01$) |
| 2. Inter-scorer reliability – considering agreement of two scorers and correlating the corresponding sets of scores. | a. For divergent item, $r = 0.692$ to $0.920$<br>b. For convergent items, $r = 0.960$ (all significant at 0.01 level) |

**VALIDITY**

| Validity | Results |
|---|---|
| 1. Face validity – school teachers' opinion towards appropriateness of the items for the students | Strong favorable opinion |
| 2. Intrinsic validity (item – item, item – total correlation ) | Range of r = 0.201 to 0.631 (all significant at 0.01 level) |
| 3. Predictive validity in relation to score on science in Madhyamik/ICSE/CBSE examination, and score on Aptitude in Physics. | r = 0.625 for Aptitude in Physics, 0.478 for science score (both significant at 0.01 level).<br>x, y, z=Score on Creativity in physics, Aptitude in Physics, Standard score on science respectively. Regression eqns. are as following:<br>$y = 0.188x + 18.04$, (Standard Error =5.02)<br>$z=0.113x+49.36$ (Standard Error=4.56) |
| 4. Concurrent validity w.r.t scores on scientific creativity measured by Majumdar's Test (1974) | r = 0.548 (significant at 0.01 level) |
| 5. Criterion validity – with respect to teachers' rating on students' creative performance in physics class using Kendall-Rank correlation. | Tau(t), significant at 0.005 level |
| 6. Content validity – in view of experts' opinion. | Favorable opinion |
| 7. Construct validity – using Principal Component Factor Analysis. | One factor extracted explaining 52.951% variance |

To interpret scores, Percentile and Stanine norms have been established over the entire sample.

The test is found to have its novelty. It is perhaps the only one of the very rare tools on Creativity in Physics having sound psychometric basis, suitable particularly in the context of physics learning of late-adolescent learners.

It incorporates the items which measure the convergent thinking ability and also divergent thinking ability, the abilities both of which are essential for learning science, in general and physics, in particular. Advanced statistical technique for scoring supported by the principle of 5- point grading has been employed as the scoring criterion for the test, rather considering mere composite score. This criterion for scoring followed by the researcher might be supported by a strong rationale. A number of criterion have been considered also for estimating the coefficients of reliability and validity of the test. Not even a single test on Creativity in Physics, as already exist, has been constructed in view of all these rational considerations. It is a test of paper-pencil type and easy to be administered. Items have been selected from the basic concepts of learning physics, therefore the higher score of a learner in this test do not imply their ability of mare memorizing and recalling information- rather indicates their ability in processing the basic information. Sub dimensions of the test are found critical, encouraging not only knowledge of fact and information of a learner, but at the same, clear understanding of various steps involved in exploring scientific knowledge in physics, thus emphasizing on both the product and the process aspect of knowledge of learners. For example, problem (figural) solving ability is one of the types of items included in the test (related SI factor-Divergent Figural Transformation, i.e. DFT, as proposed by Guilford). For solving the item, learner might utilize their knowledge of structural aspects of an image (in optics). At the same time, they will also have to recognize a two dimensional figure and perceive its three dimensional aspect- which is related to the process aspect of knowledge. A wide variety of creative dimensions were considered – but at the same time, length of the test has not been made unnecessarily long. Therefore- the test is not an exhaustive one, does not result in high fatigue among respondents- hence may be administered in a traditional classroom situation also. Set of instruction in details along with the scoring key has been provided.

The test has the scope of some improvement, as well as. First of all, the norm in the present case has been established on the basis of scores of a group containing 703 students. This size is adequate for the purpose of items analysis – but the norm could have been established over the response of a larger sample group. Students of different schools in West Bengal were used as sample in the test, scope is there to standardize it including students of other provinces. Not only that, separate norm for students of different sex and strata may also be another possible way of its improvement. Scope of including few more items of convergent dimension nurturing higher order thinking skills is also there. Predictive validity of the test could have been studied associating the scores of the test with that of an standardized Achievement Test in Physics, instead of relating the scores with the scores in science of last board examination. Not only that, a regression equation to predict achievement in Physics on the basis of creativity in physics may also have been established.

## IV. Conclusion

Administration of a standardized test on Creativity, proper scoring of responses and the subsequent interpretation are indeed time consuming. It also needs expertise and competence of a personnel having enough exposure in various aspects of educational testing. This is true particularly in case of a Test on Creativity in Physics, for psychometric construct of creativity in physics being critical, as well as multidimensional. Therefore measurement of Creativity in Physics, employing a standardized test, particularly in an institution, may not be convenient. Number of such available tests are extremely inadequate. Among the few available tests, the test of Mukhopadhyay (2011) may be used with convenience. Its ease in administration, detailed scoring key, provision of norm etc. may be successfully utilized. Such a test, particularly for higher secondary group is essential also- which may be an area of major concern of science educators. Not only for research, these tools might have relevance to the teachers in schools in identifying creative talents in physics and nurturing these subsequently.

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