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Developing Scientific Creativity Test for Senior Secondary School Students

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Abstract

The paper is based on the construction and evaluation of scientific creativity test devised for the senior secondary school students. It is an attempt that was made to evaluate validity, reliability and to determine the appropriate standards for the interpretation of the scores obtained from the scientific creativity test devised for science students. The test includes 39 items to measure three dimensions of the test which was evaluated in 220 senior secondary school students. The Content validity of the tool was evaluated by more than 20 experts and calculated by the correlation between the score of each dimension to that of the total score of the test. To decide on what items are to be retained and what to be deleted was finalized by t' test for two independent samples (i.e. high group and low group based on total scores) as the questions demanded open responses. The reliability of the test has been checked by calculating Alpha Cronbach. To identify those students who are low, high and average in scientific creativities; percentile method was used to determine the adequate cutoff score for every category. The paper dealt with the steps and procedure of how the test was constructed, evaluated, and validated. Overall it was concluded that the test has good construct and discrimination validity. Moreover, all the values of reliability coefficient for each dimension are highly significant.

Keywords: Construction, evaluation, reliability, validity, scientific creativity, senior secondary science students.

Introduction

In life, there have been problems right from the beginning of life which were been solved by a man using novel and important ideas and will need to be solved in present and future as well. It is creativity that does aid in coming up with novel solutions, gives meaning, explanation to things. It generates knowledge; create things which are original and socially, personally useful for the society. Creativity is not only the domain of painters, singers, and playwrights. It is a new idea that has value in solving a problem, or an object that is new or useful. It can mean dreaming up a solution to a challenge encountered in the laboratory. If you are doing an experiment on cells, and you want to find out why those cells keep dying, this is a problem before you. It really takes a level of creative thought to solve that problem. Feldhusen (1994) and Diakidoy and Constantinou (2001), argued that creativity is considered with reference to a specific domain in the context of learning atmosphere. They further stressed that though most of the previous researches on creativity recognized it as domain independent, but learning related particularly in education, it is domain specific by nature; its functioning in one domain is unique and psychologically differs from that of others. That is why domain specific creativity is gradually receiving more and more attention of researchers, working in the field of creativity with reference to school education.

According to MacKinnon (2005), there are different kinds of creativity. One named as scientific creativity is the ability to find out new problems and to formulate hypotheses, it usually involves some addition to our accumulated knowledge, and artistic creation may give some new orientation or representation of life or feelings thus there is a difference between scientific creativity and artistic creativity.

Getzels and Csikszentmihalyi (1967) emphasized that scientific creativity is the ability to formulate fresh questions rather than to only solve given problems. They suggested that there are various types of problem situations such as presented problem situations and discovered problem situations, requiring different kinds of thoughts for them. The discovered problem situation seems like the problem itself; remains to be discovered. Some problem solvers, like artists and scientists, do not wait for others to pose the task of identifying problems but are sensitive to identifying unformulated problems themselves. Einstein and Infeld (1938) claimed that "the formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities, to regard old problems from a new angle, require creative imagination and mark a real advance in science (p.83)." Accordingly, the discovery of new problems is often defined as the unique character of creativity in science.

Mansfield and Busse addressed five stages of the creative process in science fields:

1. The selection of the problem sensitively.

2. Extended efforts to solve the problem.

3. Deciding and using experimental, methodological and cognitive skills.

4. Changing the decisions according to the hypotheses in the 3rd.

5. Verification and elaboration need repeating the experiment.

The structure of scientific creativity has been defined by Hu, W. and Adey, P. as different from other creativity since it is concerned with creative science experiments, creative scientific problem finding and solving, and creative science activity. Scientific creativity is a kind of ability which includes intellectual factors. It must depend on scientific knowledge and skills. It should be a combination of static structure and developmental structure. The adolescents and the mature scientists have the same basic mental structure of scientific creativity but that of the mature scientist is more developed than an adolescent. Creativity and analytical intelligence are two different factors of a singular function originating from mental ability. Scientific creativity may be conceptualized as the attainment of new and novel steps in realizing the objectives of science. Moravesik (1981) has described scientific creativity as comprehending the new ideas and concepts added to the already existing scientific knowledge, in formulating new theories in science, conducting new experiments, preventing the natural laws, in recognizing new regulatory properties of scientific research and scientific group, in giving the scientific activity plans and projects originality and many other new ideas. Hu and Adey (2002) defined scientific creativity as a kind of intellectual trait or ability producing or potentially producing a certain product that is original and has social or personal value, designed with a certain purpose in mind, using given information. Heller (2007) conceptualized scientific creativity or technical creativity as an individual and social capacity for solving complex scientific and technical problems in an innovative and productive way.

Regarding the components of creativity, Torrance considered fluency, flexibility, and original thinking as main features of creativity: Fluency means the frequency of original ideas produced, Flexibility is the ability to 'change track', and not to be bound by an established way after that way is found no longer to work efficiently. Originality is interpreted in statistical language: an answer which is rare, which occurs only occasionally in a given population, is considered original.

In summary, the characteristics of scientific creativity can be as: being sensitive to any problems, ability to produce new ideas which are technologically accepted, ability to wonder, understanding the world around, ability to problem-solving, seeking solutions, designing experiments, imagination, identifying difficulties, making predictions or hypothesizing, etc

Literature Review

In this section existing scientific creativity tests were reviewed to highlight the tools that are available and justified why the present tool is being developed. As to scientific creativity of senior secondary school students, no tool was available in India; hence the investigator felt the need to develop it. At the same time several tests were having been developed for secondary students. Friedlander (1983) developed a test in which 143 he asked high school students to respond to a plant or animal stimulus through a series of divergent thinking questions, problem solving, hypothesis construction, and planning experiments. The test evidenced adequate test-retest reliability and significant correlations with criterion measures of science ability. Hu & Adey (2002), and Siew, Chong, & Chin (2014) also developed tools for scientific creativity in their own countries of UK and China respectively. In our country, India Majumdar (1975) developed the Scientific Creativity Test, which is material based test from the subjects of physics, biology, and mathematics. His main concern was to identify creative scientific talent as he felt necessity to solve

mankind's present and future problems. Also searching for such talent, Shukla and Sharma (1986), and Sinha and Singh (1987) examined the concept of scientific creativity and developed an English-Hindi instrument for measuring components of scientific creativity in secondary school students. Although these tests are very useful in measuring scientific creativity of secondary school students, they are somewhat material dependent on science knowledge, so they cannot be used for assessing scientific creativity of senior secondary school students whose scientific knowledge is high if used the same material. We believe and are of opinion that there remains a need to develop a test which can be used for assessing the scientific creativity of senior secondary school students at different ages.

Objectives

1) To construct scientific creativity test for senior secondary school students.
2) To evaluate the validity of constructed scientific creativity test.
3) To evaluate the reliability of constructed scientific creativity test.
4) To frame the norms for the interpretation of the results of scientific creativity test.

Methodology

The method adopted for the study was descriptive in nature. Here the data were collected from the senior secondary school students by administering the drafted tool to the students with necessary instructions. The data were then analyzed by using various statistical methods as per the requirement.

Sample

The initial draft of 60 items with open-ended questions was administered to a sample of 101 students of senior secondary school students who were studying in the 11^{th} classes with medical streams in Kashmir division of Jammu and Kashmir State of India with simple random sampling technique being used. The schools were affiliated to Jammu and Kashmir board of secondary education (JKBOSE). The time fixed for the said test was 60 minutes.

Construction of the Tool

There are no fixed stages of tool construction as per the literature related to the tool construction. However, it is necessary to follow a set procedure for the said purpose. For the current tool construction, the following steps were followed which are shown through the graphical representation of the tool construction as under in figure 1.

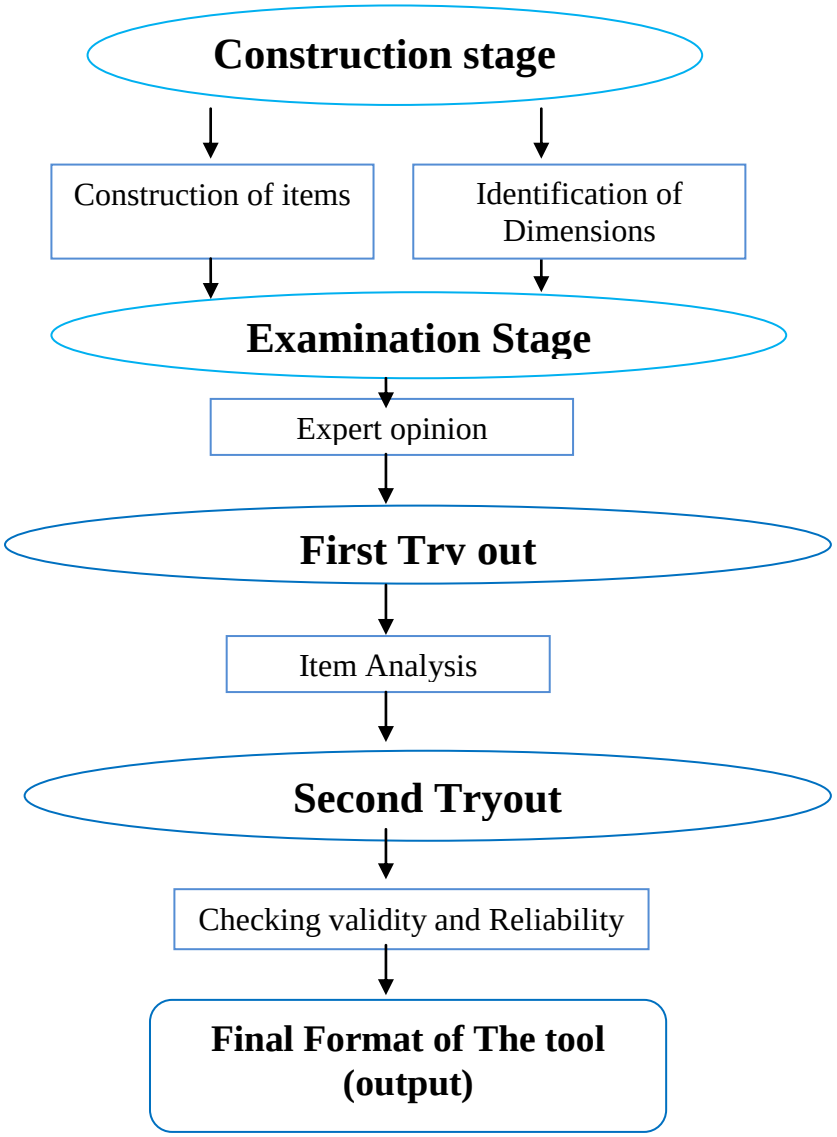

Fig.1: Stages of Tool Construction

Preparation of Preliminary Draft

Once the dimensions of the variable are being identified, the construction of items gets started to frame and is place in different dimensions as per their nature. Guilford's test of creativity was taken as the base for the construction of the tool. With the help of reviewing literature, previous tools and master's students in science subjects like physics, chemistry, zoology and botany, the items were being framed. In this way, a total of 78 items were constructed and were placed in the three dimensions of creativity namely fluency, flexibility and originality as per their nature. The nature of

the items was open ended as the test demands divergent thinking from the respondents. Then, the draft items were given to experts from different universities who were being well versed in the field and scale construction with a request to review the items and evaluate their content accuracy coverage, editorial quality and suggestions for additions, deletion, and modification of items. Based on 80% unanimity of the experts, 60 items were included in the format of the test (Table 1).

Table 1: Distribution of Items in various Dimensions for the Test

S. No.	Dimensions	No. of Items
1	Fluency	25
2	Flexibility	5
3	Originality	30
	Total	60

Item Analysis

The draft prepared was administered to the students with necessary instructions given to the students. The duration of the test was 60 minutes. The collected responses sheets were then scored as per the procedure. The procedure is that the items in fluency were scored by giving one point to right relevant and unrepeated responses to the items. For flexibility items, one point was given to one category of responses. In the originality component, frequencies and percentages were counted to obtain the scores for the items. The scoring procedure for originality is presented in the following table 2.

Table 2: Scoring for Originality

Percentage of Response in the sample	Weight assigned i.e., marks given
0.1 % to 1.0%	5
1.1% to 2.0%	4
2.1% to 3.0%	3
3.1% to 4.0%	2
4.1% to 5.0%	1
Beyond 5.0%	0

Based on the scoring procedure, the response sheets were marked and total marks were calculated for each and every answer sheet. Then the response sheets were arranged in descending order as per the total marks of the individuals. From these arranged response sheets, the above 27% and below 27% were taken as two groups named as upper and lower criterion groups respectively. As the items demanded divergent responses from the students, hence the conventional method of item difficulty could not be used. Therefore, the t-test was used to check the discrimination indices between the extreme groups of students labeled as upper and lower groups. All the items having discrimination indices significant at 0.01 levels on t-test were taken for the final draft. In this way t-test for all 60 items were calculated. A careful examination of the t-test values leads to the deletion of 21 items based on the significance of upper and lower criterion groups. The t values for the items are as under in table 3.

Table 3: Table showing t-values of the Items

Item No.	t-value	Sig.	Item No.	t-value	Sig.
1	8.593	0.000	31	4.707	0.000
2	5.687	0.000	32	0.586	0.561
3	5.431	0.000	33	2.753	0.008
4	5.124	0.000	34	4.707	0.000
5	5.572	0.000	35	1	0.322
6	4.703	0.000	36	4	0.000
7	3.709	0.001	37	-0.316	0.753
8	3.921	0.000	38	2.021	0.049
9	5.45	0.000	39	2.359	0.022
10	7.794	0.000	40	3.395	0.001
11	0.397	0.693	41	3.408	0.001
12	3.615	0.001	42	-2.753	0.008
13	2.309	0.025	43	3.674	0.001
14	3.161	0.003	44	2.753	0.008
15	2.369	0.022	45	2.767	0.008
16	3.674	0.001	46	2.342	0.023
17	4.391	0.000	47	2.021	0.049
18	5.207	0.000	48	1.789	0.08
19	5.153	0.000	49	8.718	0.000
20	5.289	0.000	50	24	0.000
21	5.466	0.000	51	-4.774	0.000
22	2.532	0.015	52	-0.316	0.753
23	4.796	0.000	53	1.206	0.234
24	2.563	0.014	54	24	0.000
25	3.541	0.001	55	0.316	0.753
26	2.294	0.026	56	3.055	0.004
27	3.395	0.001	57	4	0.000
28	-1	0.322	58	7.141	0.000
29	3.286	0.002	59	0.863	0.392
30	2.81	0.007	60	7.141	0.000

Evaluation of Test Validity

After the item analysis of the tool, it was found out that 21 items are to be deleted and then the second draft with 39 items have been prepared and printed. A separate sheet for answers was also prepared for the responses. This second draft of items along with response sheets was administered to a sample of 220 senior secondary school students who were being selected randomly from 11^{th} class science students from Kashmir to evaluate the validity and reliability of the tool. A test is said to have validity if it measures what it has the purpose to measure (Best, 1982). To determine the validity of the test, the investigator tested face validity, construct validity and discrimination validity.

Face Validity or Content Validity: The content validity of the 'Scientific Creativity Test' was tested by more than 20 experts. It is evident from the assessment of experts that items of the test are directly related to the different dimensions of Scientific Creativity.

Construct Validity: In order to find out the construct validity, the investigator calculated the correlation between the score of each dimension and a total score of the test. This is shown in table 4.

Table 4: Correlation Coefficient between each Component and the Total Scientific Creativity

scientific Creativity	Fluency	Flexibility	Originality
r	.980**	.468**	.832**
Sig.	.000	.000	.000

** Correlation is significant at the 0.01 level (2-tailed).

From the above table, it can be concluded that the correlation coefficient of all dimensions is significant. This indicates that all dimensions are related to scientific creative potential and the test has good construct validity.

Reliability of the Test: The degree of consistency among the test scores is called reliability. The reliability of the test was calculated and tested by calculating Alpha Cronbach Coefficient. The table 5 shows all the values of reliability coefficient for each domain and for the total test, are highly significant. Thus scientific creativity test is a reliable test whose reliability is 0.91 and the reliability for each dimension is .89, .82, .79, for fluency, flexibility, and originality respectively.

Table 5: Values of Reliability Coefficients for different Dimensions

Dimensions	Alpha Value
Fluency	0.892
Flexibility	0.82
Originality	0.798
Total Reliability	0.91

The Standards for Interpretation of the Test Score: To categorize the students into different categories with respect to their scientific creativity, the investigator used the standards calculated with the help of SPSS 22. The Percentiles are as given in table 6.

Table 6: Standards for Categorization

Category	Male	Female
very low	0-14	0-12.7
low	15-19	12.8-18
average	20-36	19-30
high	37-43.5	31-38
very high	above 43.5	above 39

Final Format of the Test

In this way, after going through all the above steps in a systematic way, the tool was reduced to 39 items with high reliability and validity, the description of which is given along with the time of the test to be given to students in table 7.

Table 7: The Final Format of the Test

S.No.	Dimensions	No. Of Items
1	Fluency	20
2	Flexibility	3
3	Originality	16
	Total	39

Results

After following the steps to construct and evaluate the test of scientific creativity it was found that:

- The study has produced a scientific creativity test for senior secondary school students. This test includes (39) items which measure three dimensions of scientific creativity. i.e., fluency, flexibility, and originality.

- The test has been validated through content, construct and discrimination validity. The content validity has been evaluated by experts, construct validity has been calculated by Pearson's correlation. The correlation coefficients of all dimensions are .98, .46, and .83 which are significant. This indicates that all dimensions are related to scientific creativity and the test has good construct validity. The discrimination validity has been evaluated by't' test for two independent samples (high group and low group).

- The reliability of the test was tested by calculating Alpha Cronbach Coefficient. All the values of reliability coefficient for each dimension are highly significant. Thus the scientific creativity test is a reliable test whose reliability is 0.91 and the reliability for each dimension of the test is .89, .82, .79, respectively.

- To categorize the students into different categories with respect to their scientific creativities. The investigator used the standards calculated with the help of Percentiles. Students who score up to 14 points are considered as very low in scientific creativity; 15-19 are named as low in scientific creativity, 20-36 as average in scientific creativity, 37-43.5 as high in scientific creativity and above 43.5 as very high in scientific creativity in the case of males. While as for females the students who score up to 12.7 points are considered as very low in scientific creativity; 12.8-18 are named as low in scientific creativity, 19-30 as average in scientific creativity, 31-38 as high in scientific creativity and above 39 as very high in scientific creativity

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