Developing Scientific Creativity Test

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Abstract. *This study aims to develop a test for primary school students which measures scientific creativity and scientifci process skills. A test, inspired by a Scientific Creativity Structure Model (SCSM), was used with minor changes according to the Turkish language and culture. The model includes two aspects: the processes of science and the characteristics of being creative. The test administered to year-7 students in Turkey (n=79). After suitable scoring, in order to find out if the test was valid, the expert ratings was used (n=15). The experts were the people who studied scientific creativity. The test results have been analyzed by the researchers, who study in the same area. The analysis of the data showed adequate reliability and validity.*

Keywords. Scientific creativity, scientific creativity tests, scientific processes.

1. Scientific creativity, what does it mean?

Before explaning the test items the difference between creativity and scientific creativity is going to be clarified and relationship between scientific creativity and scientific process skills are going to be stated. Basically, scientific creativity is the ability to find new problems and the ability to formulate hypotheses, it usually involves some addition to our prior knowledge, whereas artistic creation may give some new representation of life or feelings thus there is a difference between scientific creativity and artistic creativity [5].

Torrance [4] considered fluency, flexibility, and original thinking as central features of creativity: [3, 5].

Fluency means the number of original ideas produced,

Flexibility is the ability to 'change tack', not to be bound by an established approach after that approach is found no longer to work efficiently.

Originality is interpreted statistically: an answer which is rare, which occurs only occasionally in a given population, is considered original.

These features were helpful during the analyses of the answers of the test items.

Structure of scientific creativity has been defined [4] as below:

1. Scientific creativity is different from other creativity since its concerned with creative science experiments, creative scientific problem finding and solving, and creative science activity.
2. Scientific creativity is a kind of ability which includes intellectual factors.
3. Scientific creativity must depend on scientific knowledge and skills.
4. Scientific creativity should be a combination of static structure and developmental structure. The adolescent and the mature scientist have the same basic mental structure of scientific creativity but that of the latter is more developed.
5. Creativity and analytical intelligence are two different factors of a singular function originating from mental ability.

Mansfield and Busse [5] addressed five stages of 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* needs repeating the experiment

In summary, the characteristics of scientific creativity can be as follows: being

sensitive to any problems, ability to product 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 hypothesising, etc.

For measuring scientific creativity this research focused on creative thoughts and processes of scientists. In this study, students' scientific creativity can be assessed using a holistic approach; asking them questions related to their using scientific process skills.

It is believed that finding out students' scientific process skills will also show how much students' have scientific creativity components. Findings are also helpful for science teachers in order to understand their specifications as a scientist. We choose SCSM test as it is measuring scientific creativity by assessing students' scientific process skills. So that it can be found that the correlation between students' scientific creativity and students' scientific process skills.

1.1 Scientific creativity and problem solving

Creativity involves not just representing a given problem, but also finding the real problem and representing it, creative people may not be creative in their solutions but rather creative in their choices of problems [5]. Problem finding skills are increasingly recognized in theories of creativity, and problem finding has been viewed as the most important component in the creative process [5]. At the same time it is the first stage of the scientific processes. Problem finding contributes to a meaningful scientific creativity, and then scientific creativity needs to require scientific progress. The ability of problem finding or realizing problems is related to creativity when students be aware of the difficulties and need to solve a problem.

Some research [5, 8] discovered a high correlation among problem finding, divergent thinking and creative performance. Problem solving can lead to creativity because if a problem exist then tehere is the possibility of creative solution [6]. As a result of many classroom observation in junior and senior high schools, a taxonomy of students' questions (problems) for creativity was developed:

1. Factual questions that can be answered by looking in a textbook
2. questions related to scientific principles or laws that can be answered by a statement of a scientific law.
3. questions related to the ability to transfer or make applications
4. spontaneous questions of curiosity
5. questions that are genuine problems that need to be solved

Another categorisation includes four levels of questions [5]:

1. memorised statements
2. descriptions, classifications or comparisons
3. experiments/variables must be made specific, measurable,manipulable
4. experiments/variables are already specific, measurable, manipulable

After developing the test further study is also going to explore the types of students' questions according to the qoutations above.

1.2 What is the relationship between scientific creativity and scientific process skills?

Scientific research requires creativity in the sense of creating new understanding, solving problems in science requires a student to explore his/her own repertoire, to imagine a variety of routes to a solution. This is the justification for considering scientific creativity as worthy of attention in the education of students who will either become scientists or who need an understanding of society [4].

The aim of investigative work is to give opportunities to students for to solve a problem using their skills and their conceptual framework [2], by doing this students learn the scientific processes essentially. These skills can be grouped within 5 major categories (Şahin Pekmez, 2000):

1. Identification of the problem and making hypothesis.
2. Designing the experiment by deciding the variables.
3. Making measurements, observation and finding the evidence and defining them.
4. Presentation of the data using tables and graphs.

5. Evaluation of the process by critisising the validity and reliability of the data and drawing conclusions.

In somewhere else these skills are stated as the following: ***Basic skills:*** Observation, classification, communication, measurement, estimation, prediction, inference. ***Integrated skills:*** Identifying, controlling variables, defining operationally, hypothesising, experimenting, graphing, interpreting, modellling [7].

The skills are also encompassed within 4 major categories [1].

1. *Formulation* includes identification of the problem, hypothesising, prediction of the outcomes, and planning of the study.
2. *Implementation* includes observing, making measurements and recording.
3. *Evidence* involves analysing and interpreting the data, and drawing conclusions.
4. *Explanation* entails providing the link between theory and the findings.

The categories below are actually stating scientific process skills which have components of scientific creativity. Investigative activities, which include scientific process skills, could be included in both hands on and minds on science. Students both use their skills and conceptual knowledge or experience during practical experiences. If the students engage with investigative work they become more creative in deciding the variables, method and equipment etc.

The creativity component of the investigative work could be measured checking the students' skills of asking a suitable question and deciding the variables, planning experiments, trying different methods. It is believed that the test items in this research have include both components of scientific creativity and scientific process.

2. Methodology

This study aims to develop a test, which is designed mainly to measure scientific creativity. The scientific creativity components are related to scientific process skills. The test was designed to check primary students' (year-7) scientific creativity. The test is inspired from SCSM-Scientific Creativity Structure Model [4]. Hu and Adey suggested that the test needed to be administered to more students in order to validate the test. They also added larger samples from different cultures should be investigated. The first draft of the test was was administered to 60 secondary students in England by Hu and Adey.

2.1 The development of the test

Actually the test has been developed before for secondary school students. In this study we have choosen the SCSM test. Some questions of the original test have been modified according to the Turkish language and culture, and some other questions have been added according to the Turkish language and culture. The test was administered to a sample of 79 students selected from year-7 in a primary school in Turkey. The school was a suburban mixed comprehensive school with a broad ability range. 56% of the students (n: 19) were female and 44% (n: 70) were male. All of the students are 12 years old.

2.2 Description of the test

Pupils were required to answer the questions in a 40-minute time, which was the period of a lesson. They were informed by verbally to give their personal details, like sex, age and name, and also the teacher encouraged them by having said that their quality of being a scientist was going to be measured.

Below the items are presented with original ones by explaining with their scientific creativity components and their scientific process skills component. We would prefer to call this test 'Scientific Creativity and Scientific Process Skills' (SCSPS). (In the original test the researchers helped students by giving them examples for items 1-4. However, in this study no help was given in order to differentiate the findings as scientific creativity or not).

2.2.1 Item 1

Original: *Please write down as many as possible scientific uses as you can for a piece of glass. For example, make a test tube.*
SCSPS: a) *Please write down as many as possible scientific uses (for example in a lab) as you can for a plastic bottle.*

b) *Please write down as many as possible scientific uses (for example in a lab) as you can for a can.*

In the original test this task is designed to measure the fluency, flexibility, and originality in using an object for a scientific purpose. In SCSPS, this includes hypothesising and problem finding and solving as scientific process skills, and also producing new ideas, being sensitive to problems as scientific creativity components.

2.2.2. Item 2

Original: *If you can take a spaceship to travel in the outer space and go to a planet, what scientific questions do you want to research? Please list as many as you can. For example, are there any living things on the planet?*

SCSPS: *If you can invent a time machine, which time do you want to go? What scientific questions do you want to research? Please list as many as you can.*

In the original test the aim of this task is to measure the degree of being sensitive to science problems. In SCSPS, this includes asking questions thus finding problems as scientific process skills, and also ability to wonder, being sensitive to problems as scientific creativity components.

2.2.3. Item 3

Original: *Please think up as many possible improvements as you can to a regular bicyle making it more interesting, more useful and more beautiful. For example, make the tyres reflective, so they can be seen in the dark.*

SCSPS: *Please think up as many possible improvements as you can to a regular school bag, making it more interesting, more useful and more beautiful and please tell why you need the improvements you stated and how could you prove that your suggestions are suitable?*

The third task is designed to measure students' ability to improve a technical product. In the present study, we used the school bag as an object. Because it is thought that our students have problems about carrying it. In SCSPS, this includes hypothesising, designing experiment, evaluating the data as scientific process skills and ability to produce new ideas technologically accepted as creativity components.

2.2.4. Item 4

Original: *Suppose there was no gravity; describe what the world would be like? For example, humanbeings would be floating.*

SCSPS: *a) Suppose there was no night, always daytime, describes what the world would be like?*
b) Suppose the world is not turning around the sun, describes what the world would be like?

The purpose of this task is to measure students' scientific imagination. In SCSPS, this includes hypothesising, estimating, explaining the results and making comments as scientific process skills; and ability to wonder, understanding the world aound as creativity components.

2.2.5 Item 5

Original: *There are two kinds of napkins. How can you test which is better? Please write down as many possible methods as you can and the instruments, principles and simple procedure.*

SCSPS: *There are two kinds of toilet papers. How can you test which is better? Please write down as many possible methods as you can and the instruments, principles and simple procedure.*

The purpose of this item is to assess creative experimental ability. In item 5,6,7 real-life types of problems were used because they gave evidence that when real-life types of problems are used there is a stronger correlation with other domains in creative performance [8]. Here instead of napkins it was used toilet paper. The reason for this is that there is a TV commercial about this and we use this analysing the item if students use the idea of TV commercial or think about some other ways. In SCSPS, this includes ability to problem solving like deciding the variables and the method, measuring etc. as scientific process skills; ability to problem solving, ability to wonder, seeking solutions, designing experiments, imagination, identifying difficulties, making prediction, being productive as creativity components.

2.2.6. Item 6

Original: *Please design an apple-picking machine. Draw a picture; point out the name and function of each part.*

SCSPS: I*t is the same with the original item*

This task has been designed to measure creative science product design ability. In SCSPS, this covers hypothesising, designing experiment, evaluation of the whole process as scientific process skills; seeking solutions, designing experiments, imagination, and producing new product as creativity components.

2.3 Scoring

We used the same scorring system for the items 1 to 4. 'Frequencies and percentages of each response are computed. If the probability of a response is smaller than 5%, we give it 2 points; if the probability is from 5 to 10%, we give it 1 point; if the probability of a response is greater than 10%, we give it 0 points'.

For item-5 we follow the similar procedure. First we planned to classify the answers into two categories: students who give different methods and students who just say the independent variable without suggesting any method. However, the answers were divided into two like this: students whose methods were just the same as the TV commercial and students who just stated some independent variable. Thus, we decided to score the answers according to the number of independent variable: If the students answer is the same as the TV commercial it gets 0 point, how many independent variable the students state they get the same amount of point for example if the students give one independent variable it gets 1 point. The maximum point was 4 (independent variables: price, quality, softness and length of the toilet paper).

For item-6 again the original scoring system was used: "the score of the task is decided by the functions of the machine. The functions could be reaching the apples, finding the apples, picking the apples, transporting the apples to the ground sorting out the apples… and each function got 3 points.

2.4. Analysing the items

First, the item discrimination was calculated in terms of a t ratio, taking the upper and lower 27 percent cases of the sample. Items were only considered for the final form of the test if the t value is significant at the 0.01 level or less ($p<0.01$).

Secondly, for the reliability the scoring system was interpreted by someone who had not been involved in the test development and agreement between two persons was calculated by Pearson product-moment correlation coefficients between the two sets of scores are presented in table 1. The correlations between scores vary from 0.89 to 1.00 with a median of. 0.94 The results suggest that the scoring procedure is adequately objective.

Table 1. Agreement between two scorers.

Scorer Agreement (n = 79)	
1a	0.92
1b	0.89
2	1.00
3	0.96
4a	0.94
4b	0.91
5	1.00
6	0.92

2.4.1. Validity

The type of validity determined in this study is the face validity: do the items include the components of scientific process skills and scientific creativity? To obtain a measure of face validity of the test, 15 people of science education researchers and science teachers from Turkey were asked the question s above.The results are shown in table 2, suggesting a high degree of face validity amongst science education researchers and science teachers.

Table 2. Face validity: teachers and science educators.

	Responses (n = 15)	
	yes	no
1a	15	
1b	15	
2	15	
3	15	
4a	15	
4b	15	
5	15	
6	15	

Analysis showed adequate reliabilities and validities.

3. What is next?

After developing the test the purpose of the further study will be finding out students' scientific creativity and students' skills of using scientific processes. Additionally, another test will be developed that measures only scientific process skills of students. We believe that there is a connection between scientific process skills and being creative scientifically and that is one of the reason why we should use investigative activities. The better students have the scientific process skills the more they are creative and problem solver. Not only our findings will show that our belief is true or not but also they will describe the situation of our school science.

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