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Assessment ofopen-ended questions directed to prospective science teachers in terms of scientific creativity

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Abstract

Innovation is mandatory for development in every part of social life. In knowledge societies, education's role is not to re-create society, but to create "new society" (Baykal, 2003). Scientific knowledge is partially product of imagination and creativity (Khishfe and Abd-El-Khalick, 2002). Creative thinking is posing different and unique ideas for any situation or problem in daily lives and generating multidirectional solutions, combination of cases, concepts and objects by relating them to each other and construct new experiences, differing from paths that everybody is accustomed to (Temizkan, 2011; Öznacar and Bildiren, 2012). Creativity involves both scientificity and daily life (Farooq, 2008). As a matter of fact, problem solving, constructing hypothesis and experiment and technical innovation require specific form of scientific creativity (Lin, Hu, Adey and Shen, 2003). According to Kocabaş (1993), scientific creativity can be defined as motivation for scientific research, formularization of knowledge and research problems, constructing a general domain for solution of a scientific question, research ability appropriate to causes and similarities, patience and resistance for a detailed research.The purpose of the study is to assess prospective science teachers' answers to open-ended questions in terms of scientific creativity. For this purpose, prospective science teachers were asked 3 open-ended questions. The data gathered from the study were examined in terms of "fluency, flexibility, originality and scientific knowledge" which are the features of scientific creativity and expert validity was established. Qualitative data gathered from the study was also presented as numbered quantitative data and they were discussed comparatively within. Prospective science teachers' scientific creativity assessments were made according to the findings of the study and some related recommendations were presented about scientific creativity skills.

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Keywords: scientific creativity; creativity; prospective teachers.

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1. Introduction

Education systems which are common across the world should keep up with rapid social changes, global economic structures and technological development (Bellofiare, 1999; Bentley, 1998; Burbules and Torres 2000; Selzer and Bertley, 1999) (cit. by Kind and Kind, 2007). Creative student education makes contribution to individuals to keep up with innovations in their own lives. For that reason, creative teaching is considered to be crucial. Creativity should be emphasized in every school program. Courses about science will both help development of students' scientific creativity concepts and prepare them for future (Kind and Kind, 2007).

Creativity involves both scientificity and daily life (Farooq, 2008). As a matter of fact; problem solving, constructing hypothesis and experiment as well as technical innovation require some specific form of scientific creativity (Lin, Hu, Adey and Shen, 2003). According to Kocabaş (1993), scientific creativity can be defined as motivation for scientific research, formularization of knowledge and research problems, constructing general space for solution of a scientific question, research ability appropriate to causes and similarities, patience and resistance for a detailed research. Park (2011) stated that scientific creativity consists of three dimensions: creative thinking, scientific knowledge and scientific inquiry skills. Creativity in science teaching is examined under the subheadings of creativity teaching, art and science, inquiry and science as well as nature of science. Scientific creativity could be regarded as reaching new and unique steps for establishing purposes of science (Aktamış and Ergin, 2006). Scientific creativity model and test developed by Hu and Adey (2002) consists of three main dimensions: process (imagination, thinking), characteristics/features (originality, flexibility, fluency), product (scientific problem, scientific fact, scientific knowledge, technical product). According to Demir (2014), scientific creative thinking ability can be defined as "thinking ability that brings together interdisciplinary areas of science, technology and art (aesthetic) and provides individuals' unique solution ideas of a challenging problem from these areas' points of views". As it can be seen from this definition, scientific creativity brings together both the uniqueness of the discipline and different disciplines' aesthetic aspects. It is considered as a multidimensional and sophisticated field (Demir, 2014).

For creativity and creative teaching programs; teachers should make efforts to make learning more interesting, exciting and effective by using creative approaches (Demir and Şahin, 2013). "Good qualified" creative teaching and "badly constructed" traditional teaching designs which were mentioned in different studies and put together by Kind and Kind (2007) are presented below.

Table1. Creative-Traditional Teaching

Creative Teaching	Traditional Teaching
Student centered	Teacher centered
Needs cooperation	Individual studies
Open-ended problems	Close-ended problems
(Hands on) teaching	Close-ended experiments
Outdoor activities	Limited to classroom activities
Teachers who can take risks	Teachers who can't take risks
Project-based	
Problem focused	
Open-ended inquiry	

As it can be seen from the table, open-ended questions can be seen as one of the methods in creative learning. Aktamış and Ergin (2006) stated that quasi open-ended questions could be used for the development of scientific creativity in science education. They also specified just problems (open ended) or topics (so that students could find the problem) could be given to students in some activities. Likewise, Demir (2014) showed the important effect of simple equipments and developing open-ended ideas on prospective teachers' scientific creativity and science process skills as well as underlined the importance of development of scientific creativity skill on social progression

From this point on, the research question of this study is "What is the adequacy of prospective science teachers' responses to open-ended questions in terms of four criteria of scientific creativity?"

2. Method

The research was conducted with 24 prospective science teachers majoring science teaching department at second grade at a university in İstanbul. "Fluency, flexibility, originality and scientific knowledge" are the assessment criteria for prospective science teachers' responses to 3 open-ended questions.

For the assessment criteria for the open ended questions, the original scientific creativity test developed by Hu and Adey (2002), Turkish versions of the test adopted by DenişÇeliker andBalım (2012) and Kadayıfçı (2008) and the implementation process of Demir (2014) were benefited for the assessment of the open-ended questions. According to these studies, for the 1.and 2. open-ended questions in the questionnaire, every single answer's frequency constructs fluency scores, each different aspect (category) in the question forms the flexibility scores and all of the answers' frequency generates originality scores. When calculating the originality scores, through all of the true answers considered as fluent, the ones that are in 5% of the answers have 2 points, the ones that are in 5% and 10% have 1 point and finally the ones that are in more that 10% of the have 0 point.

For the 3rd question of the study, "design an apple picking machine" question developed by Hu and Adey (2002) was benefited. For the assessment of this question, Hu and Adey's (2002) and DenişÇeliker and Balım's (2012) assessment protocol was used. According to this, flexibility scores was calculated by the definition of different approaches (categories) to the question and originality scores were constructed between 1-5 points.

A rubric developed by Demir (2014) was benefited for the originality points' value ranges. It is a 5 point Likert-type scale consists of dimensions from quite insufficient to quite sufficient. Defining the lowest and highest point range determine the value ranges for each of the questions. For the first question, the range is determined between 0-176 points and 0-134 points for the second question. The same technique was adopted for the third question of the study; assessment of the originality was made with 5 point Likert type scale test.

The adequacy of prospective science teachers' scientific creativity is determined in terms of 4 dimensions for the open-ended questions. In this manner, the research design of the study is "case study". According to Yin (2003), case study can be defined as conducting an empirical investigation of a contemporary phenomenon within its natural setting using various data gathering tools and techniques.

3. Findings

The qualitative data gathered from three open-ended questions (two of the questions are related with short stories and one of them is designed as a drawing question) were assessed by quantifying them.

The first open-ended question of the study is "The plants grew well and healthy in your garden previously. In the last years, they aren't fertile and they don't develop even though they get enough rain and sun light. You are the responsible of the garden and how could you make plants develop better as before?"

Table2. Findings for the "Plant Development" Question

Categories		N	Orj.
1.	Check out for minerals/elements	22	0
2.	Soil is fertilized	18	0
3.	Growth hormone is given/injected	2	2
4.	Check out for microorganisms	1	2
5.	Disinfection	8	1
6.	Weeds are removed	2	2
7.	Plant is pruned	5	1
8.	Protection against the weather conditions	1	2
9.	Soil is vented	7	1
10.	If there is any chemical matter or waste, it is located	4	2
11.	Check out the pH value and acidity of soil and rain water.	3	2

12.	Different planting to soil	3	2
13.	Soil is renewed	3	2
14.	Soil is rested	2	2
15.	The seed construct could be modified	2	2
16.	Check out for angle and wave length of the sunlight	2	2
17.	Soil is cleaned	2	2
18.	Plant is supported	1	2

Fluency =88 points, originality = 52 points, scientific knowledge =107 points

As it can be seen from the table, fluency point is 88 and 18 categories (flexibility) are obtained whereas originality score is insufficient with 52 points in total.

The second open-ended question of the study is "There is a sun panel in your chalet. But when the sun is not enough or when it gets dark, you cannot produce energy. In this situation, how would you produce your own energy? Create many ideas as possible."

Table3. Findings for the "energy production" question

Categories		N	Orig.
1.	I store energy which was produced in the day	13	0
2.	I produce wind energy	18	0
3.	I produce water energy	13	0
4.	I produce it from fossil fuels	3	2
5.	I produce it from recycling/garbages	4	1
6.	I produce it from movement/bicycle energy	4	1
7.	I light a fire	3	2
8.	I produce it from candles, lamps etc...	3	2
9.	I produce it from moon light	2	2
10.	I produce it from hot water sources nearby	1	2
11.	I produce it from steam pressure	2	2
12.	I produce it from battery, wire...mechanisms	1	2

Fluency = 67 points, originality = 38 points, scientific knowledge = 106 points

As it can be seen from the table, fluency score is 67 in total and 12 categories (flexibility) are obtained whereas originality score is insufficient with 38 points in total.

The third question of the study is "Please design a coffee mug that keeps heat the same (the main feature of the mug is that). Draw your design, define and name each part of the mug. Finally give a name to your design."

Table4. Findings for the "Mug Coffee" Drawings

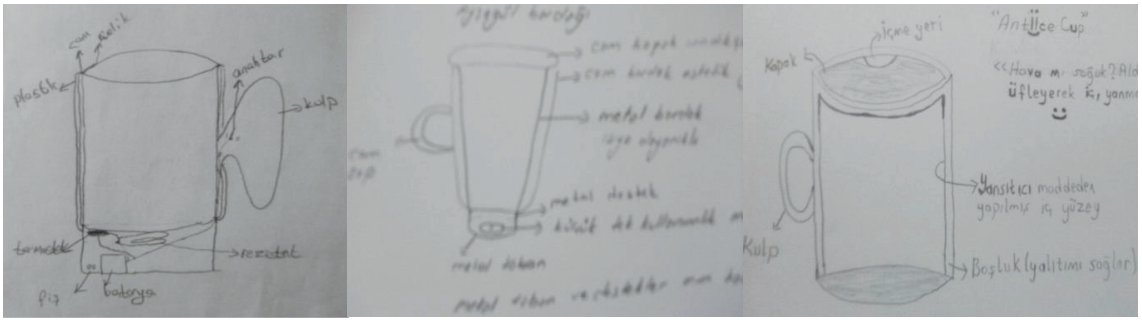
Categories		N
1.	Metal-carton	1
2.	Thermostatic paper	1
3.	Ceramic	1
4.	Glass	2
5.	Mica+ Aluminum	1
6.	Thermos flask+ plastic	1
7.	Rotary wing+ Heater	1
8.	Thermos flask + ceramic	1
9.	Aluminum foil	1

10.	Candle+ metal	1
11.	Aluminum + Plastic	1
12.	Sun energy+ battery	1
13.	Soil +clay+glass	1
14.	Metal +plastic+ battery	1
15.	Glass +battery+ plastic+ steel	1
16.	Others	8

Fluency = 77 points, scientific knowledge = 110 points

As it can be seen from the table, 18 categories (flexibility) are obtained whereas originality score is partially sufficient with 77 points in total.

Some examples from prospective teachers' drawings for this question are presented below.



Quite adequate Partially Quite inadequate

Figure 1. Examples for coffee mug drawings in terms of originality

For the third open-ended question, the drawing examples were assessed according to originality points whether they were quite inadequate or quite adequate and some of the drawings were presented above as examples.

4.Results and discussion

Wei, Chang, Hsieh and Yang (2006) underlined that the aim of science education is not just to transfer or teach knowledge and other disciplines such as mathematics, art, life, technology could participate in. They also mentioned there are important differences in fluency, flexibility, originality and specification with creative learning processes and activities. The results of the study showed that showing ideas (fluency) and developing ideas in different categories (flexibility) are more in the first question compared to second question. This situation could be related to the problem contexts. For the originality criteria of the scientific creativity skill, it is found out that prospective teachers are insufficient. For the third question of the study, prospective teachers' drawings are partially sufficient in originality. Additionally, prospective teachers are sufficient in scientific knowledge criteria for all of the questions. This shows the importance of subject matter knowledge for scientific creativity.

For this reason, it is necessary that more constructed opportunities in terms of scientific creativity should be made. Likewise, Demir and Şahin (2013) and Demir (2014) underlined the importance of the development of scientific creativity on social progression. According to YanparYelken's study (2009), developing materials based on creativity have positive effects on prospective teachers' portfolios and in this study; open-ended questions were used for that purpose. According to Demir's study (2014), it is determined that open-ended questions should be used efficiently in scientific creativity laboratory program and among the dimensions of scientific creativity, especially

fluency, flexibility and originality should be developed. Garg and Garg (2002) proposed need-based education program besides creative thinking and problem based learning for developing creativity in science education. Likewise, 2013 science education curriculum program aims to raise scientifically literate individuals who can investigate and inquire, solve problems and communicate. In the "skills" dimension, science process skills, analytical thinking, creative thinking and communication are underlined (MEB, 2013). Moving from this study, it is considered that development of prospective teachers' scientific creativity should be regarded as crucial for they will raise leaders of the society and activities based on this direction should be increased.

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