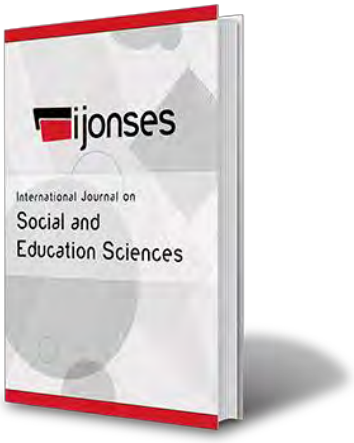

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Hamza Erdem Şişman
Ministry of Education, Science and Arts Education Center, Turkey

Nilay Aydoğan
Inonu University, Turkey

Özlem Çankaya
Inonu University, Turkey

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A Scientific Creativity Scale Development Process for Science Teacher Candidates

Hamza Erdem Şişman, Nilay Aydoğan and Özlem Çankaya

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Abstract

This study aims to prepare a scale to determine the creativity levels of prospective teachers studying at the undergraduate level of science teaching. In this context, 15 questions, suitable for student's level from physics, chemistry, biology, astronomy and ecology sub-branches were prepared. The questions were assessed by 5 lecturers who were experts in their fields for their opinions. After the expert opinion, the number of questions was determined as 13 and pilot study was carried out with 95 pre-service teachers studying in Inonu University Faculty of Education Science Teacher Education. The data obtained from the pilot study were analyzed by using SPSS 21.0 statistical program according to Multi Surface Rasch Model. In order to determine the reliability of the scale, internal consistency coefficient of Cronbach's alpha was calculated and found .758. At the end of the research, the data was analyzed and the question number of the scale was determined as 10 according to the analysis results. Studies conducted on scientific creativity generally aimed to measure the scientific creativity of secondary school students. We believe that a deficiency in measuring the scientific creativity of undergraduate students at the academic level will be eliminated with the scale we developed.

Introduction

The expectations of societies from people are changing with the developing technology. As a result of rapid globalization and technological progress, requirements shift from standardized tasks to more complex and non-routine activities (Yazar, Levy & Murnane, 2003). Professionals are required who can analyze and solve problems, think critically, and communicate effectively, which requires the need to build relevant knowledge and skills (Sidek et al., 2020). People with these characteristics will accelerate the process of reaching the development targets of society and ensure that this level is maintained dynamically. Knowledge, creativity, and practical intelligence are needed to solve problems. The basis of problem-solving does not depend only on knowledge. For this reason, people do not offer the same solutions to the same problem, which shows that besides knowledge, creativity is also necessary for problem-solving (Aktamış & Ergin, 2007).

Creativity is a multifaceted concept that has been investigated from different perspectives and can be viewed as "the ability to generate work that is both new and relevant", expressing four aspects of creativity, the process of formation, the pursuit of purpose, innovation, and value appraisal. Creativity is specific to science, rooted in

certain knowledge or discipline fields, and includes scientific creativity (Sidek et al., 2020).

Creativity plays key roles in research and innovation processes. It can be understood as a combination of different skills, knowledge, motivation, and attitudes people employ to evaluate various input ideas from different perspectives and dimensions to create a new, valuable, and original idea or product (Henriksen et al., 2016). Creativity is a fundamental ability, which must meet the standards of competition in the information and information age and the challenges of an increasingly complex future require a creative generation capable of innovation (Mayasari et al., 2016; Ritter et al., 2020). According to Norris (2018) the creativity is important higher-order cognitive skills needed for the twenty-first century (Ling & Loh, 2020). Creativity also can be defined as "the ability to use skill and imagination to produce something new or to produce art; the act of doing this" (Creativity, n.d.) (Hoeg & Bencze, 2014).

There are many definitions of the creativity concept, but it is difficult to find a common definition that provides consensus. When we want to define creativity, a complex phenomenon occurs in our minds which could not fit into simple sentences. It exists at every stage of life and is considered a very important product emerging as a result of learning and must be considered along with education (McWilliams, 2009).Despite the debate over whether creativity is general or field-specific, no doubt, science is a creative pursuit. Scientists must be creative to come up with new ideas to explain a phenomenon or innovative ways to solve a problem.

At first glance, science may not seem to have a reputation for being very creative. Although scientists "must stick to the scientific method, employ statistics and data, and measure their outcomes carefully - activities that appear to discard the magic of the creative process" (Ossola, 2018, p. 1); however, we could not deny that some of greatest scientific innovators were creative thinkers. These creative aspects of scientists and the psychological dimensions of their creativity have been the subject of many studies by many researchers (Migdal, 2006).Although scientific creativity may appear less creative as it is more tangible or real than depictions of artistic creativity, both forms are grounded in the innovation desires of previous artists and scientists (Ossola, 2018; Gomes & McCauley, 2021).

Individuals can show their creativity in different fields. For example, a person may be creative in the sciences but not in artistic fields. For this reason, it is necessary to keep scientific creativity separate from other creative types. Although scientific creativity brings some additions to the previous knowledge, artistic creativity can occur suddenly in all areas of life, but there is usually no progress in the previous ones in this regard (Aktamış & Ergin, 2006).

Aktamış and Ergin (2006) reported that creativity related to science was expressed as "scientific creativity" and emphasized that it is necessary to separate scientific creativity from general creativity in many studies. Because they also argued that scientific creativity emerged when faced with a problem.One of the scientists who put forward the idea that creativity must be examined on a field basis was Baer (1998), who found a very low relation between subjects' creativity scores in his studies on subjects in different fields such as mathematics, literature, and music. As a result of his study, he concluded that creativity is specific to the field.Grosul (2010) considered scientific creativity as a talent of scientists. According to Grosul, people with scientific creativity are inclined to

produce extraordinary and useful scientific knowledge. Rawat (2010) defined scientific creativity as a scientific ability that must be possessed to produce new products in the field of science and technology. According to Thomas and Chess (1977), scientific creativity is the ability to bring extraordinary and practical knowledge to the scientific world by using scientific methods and techniques (cited by Rawat, 2010).

In general, creativity, and in particular, scientific creativity are key competencies to shape the future in an innovative, sustainable, and resource-saving way. Sternberg (2010) and Ghassib (2010) emphasize the importance of scientific knowledge, creativity, and wisdom in the progress of societies. For this reason, young people must be prepared and trained in high-level thinking skills such as creative and critical thinking (Pacheco & Herrera, 2021). They must also learn to cope with new situations for which they do not have a prepared strategy, and be able to think flexibly and creatively about how to overcome the obstacles on the way leading to the solution (Kind & Kind, 2007; Marope, Griffin & Gallagher, 2017; OECD, 2014).

Many science educators agree that creativity is a very important component of school science (Park, 2011; Rutherford & Ahlgren, 1990). Teachers play important roles in encouraging creativity in students as mentors and role models. Researchers argued that teachers must be aware of the meaning and importance of creativity to facilitate students' creativity, realize their creative potential and creative output, and encourage these abilities and attitudes regarding creativity (Aljughaiman & Mowrer-Reynolds, 2005; Diakidoy & Kanari, 1999; Sak, 2004). To encourage students to think creatively, teachers must enable them to formulate hypotheses for the solution of a problem, design experiments, and follow technological developments (Lin et al., 2003).

After the increased importance given to creativity, intra-class activities aimed at improving the creativity levels of students have begun to be added to the curriculum in recent years. In this sense, science education plays the most important role in increasing the level of creativity (Daud, Omar, Turiman & Osman, 2012).Creativity is formed with the combination of four different components, which are a creative process, creative state, creative product, and creative person. If these components are realized properly, the development of creativity will be inevitable (Orhon, 2011).

National Advisory Committee on Creative & Cultural Education (NACCE) (1999) defined creative education as the one provided to people to find solutions to their demands in the changing world. Creative student education enables individuals to find solutions to their demands directly. To raise a creative generation that can stand on its own feet, creative thinking education must be included in every school curriculum (as cited in Kind & Kind, 2007).

This education can be performed more efficiently with teachers who have high scientific creativity. The Scientific Creativity Scale, which was developed by Hu and Adey (2002) for secondary school students, is used in a limited number of studies conducted with undergraduate students in the literature review on scientific creativity. In current study, we aimed to develop a scientific creativity scale to determine the scientific creativity levels of science teacher candidates studying at the undergraduate level. Therefore, this study aims to make a contribution to fill the gap in this direction.

Method

Model of the Study

95 undergraduate students studying at different levels of the science teaching program participated in the study. The analysis of the scores given to the answers of 95 undergraduate students who participated in the study was made by using the SPSS 21.0 statistical program according to the Multi-Surface Rasch Model. Exploratory Factor Analysis (EFA) was performed over the averages of the scores given by the raters for the unidimensionality assumption. Before EFA, it was determined whether the data were suitable for factor analysis with Kaiser-Meyer-Olkin (KMO) and Bartlett Test.

Universe and Sampling

The study was conducted with 95 science teacher candidates studying in the 2nd and 3rd grades of Inonu University Science Teaching Department in the 2018-2019 academic year. The scale was scored by two different raters to increase the reliability of the scoring. The gender and grade information of the teacher candidates participating in the study are given in the Table 1.

Table 1. The Demographic Characteristics of Students Who Participated in the Pilot Scheme

Student	Female	Male	Total
Grade 2	38	10	48
Grade 3	34	13	47
Total	72	23	95

The Development Process of the Scientific Creativity Scale

In the process of developing the Scientific Creativity Scale, firstly, a literature review was performed and a field study of the questions to be included in the scale was conducted. For the questions to be suitable for the levels of students studying at the undergraduate level, 15 open-ended questions that covered physics, chemistry, biology, ecology, and astronomy fields were prepared by considering the scientific process skills and theoretical knowledge infrastructure of students. To determine that the construct validity of the questions in the designed scale was at an appropriate level, it was examined by 5 faculty members who were experts in the field of educational sciences and natural sciences. It was not necessary to examine the content validity as the scale will not be used to determine the academic achievement of students.

The experts examined the questions based on the criteria of clarity, fluency, effective use of language, and appropriateness of scientific expressions and provided feedback. This process increased the validity and reliability of the scale (Çalık & Ayas, 2002). In line with the feedback of the experts, one question was removed from the scale because it was aimed at measuring the knowledge level of students rather than scientific creativity, and another question was evaluated for misconceptions. Also, by considering the opinions of the experts, a few questions at the beginning of the scale were changed, since they were challenging, and made ready for the Pilot

Scheme.

Open-ended questions are one of the measurement tools employed in education where students can give their thoughts freely in written form without any limitations (Gronlund, 1998). Open-ended questions allow students to present original ideas and are the most appropriate question type to measure students' high-level skills such as exploring the given problem, forming hypotheses, establishing cause-effect relations, and producing new ideas (Tan & Erdoğan, 2004).

Open-ended formats also include short answers, fill-in-the-blank, free answers, concept mapping, and diagramming. Each format has different possibilities and limitations, therefore, educators face the task of weighing the ability of different formats to assess student thinking against the time and resources required to develop, administer, and score assessments. Inferences are made in the open-ended format based on the existence and accuracy of the same concepts that students can include in their answers as well as in other concepts (Hubbart, 2017).

When compared to other measurement tools, some other advantages of open-ended questions are that they measure higher-order thinking skills better, the chance factor is almost zero, and they are suitable for partial scoring (Turgut & Baykul, 2012). Although open-ended questions provide convenience when compared to other measurement tools in terms of preparation, they also make the work of raters very difficult during the evaluation stage (Başol, 2013).The way to measure scientific creativity will only be possible by freeing the minds of students. For this reason, the scale was created with open-ended questions.

Pilot Scheme of the Scientific Creativity Scale

The Pilot Scheme of the draft scale, which was reduced to 13 questions after expert opinions, was performed with the participation of 95 students studying in the 2nd and 3rd grades of Inonu University Faculty of Education Science Teaching. Students were given 60 minutes for 13 open-ended questions in the Pilot Scheme, whose participation was voluntary. Since the ethics committee of the university was not established at the time the study was conducted, it was completed with the approval of the participants.

Evaluation Process of Scientific Creativity Scale

The evaluation process of the Scientific Creativity Scale was initiated with the preparation of the evaluation rubric just before the Pilot Scheme. The rubric that was prepared by Hu and Adey (2002) based on the assessment guide of the scale prepared to measure the scientific creativity of secondary school students based on the Guilford Theory (1967) is given in Table 2.

To reduce the reliability problem that emerges in the evaluation of open-ended questions, the questions were evaluated by two raters who are experts in their field. As a result of the evaluation, the scoring showed consistency of 95%. The conflicting 5% scoring was clarified after the consensus of the experts.

Table 2. Scientific Creativity Scale Evaluation Rubric

Scientific Creativity Scale Evaluation Rubric				
Questions	**Sub-content**	**Fluency Score**	**Flexibility Score**	**Specificity Score**
Question 1	Product Development	1 point for each answer produced	1 point for each different answer proposed (1) Land vehicles (2) Water vehicles (3) Air vehicles (4) Chemicals	2 points for each answer found in people fewer than 5% 1 point for 5%-10%
Question 2	Discovering the Problem	1 point for each answer produced	1 point for each proposed science experiment field (1) Physics (2) Chemistry (3) Biology (4) Ecology (5) Astronomy	2 points for each answer found in people fewer than 5% 1 point for 5%-10%
Question 3	Scientific Imagination	1 point for each answer produced	1 point for each different answer proposed (1) Structure of the planet (2) Production (food, oxygen) (3) Electronic parts (4) Transport vehicle (invention) (5) Saving	2 points for each answer found in people fewer than 5% 1 point for 5%-10%
Question 4	Scientific Imagination	1 point for each answer produced	1 point for each different answer proposed (1) Human life (2) Physics rules (3) Scientific work (4) Climate, meteorologic events (5) Biologic factors	2 points for each answer found in people fewer than 5% 1 point for 5%-10%
Question 5	Science Experiment	4 points for each answer found in people fewer than 5% 2 points for people between 5%-10% 1 point for an answer found in people more than 10% (combination of fluency and specificity)		

Scientific Creativity Scale Evaluation Rubric				
Questions	**Sub-content**	**Fluency Score**	**Flexibility Score**	**Specificity Score**
Question 6	Science Experiment	1 point for each out-of-laboratory item used in the experiment, 3 points for methods with scientific validity		4 points for each answer found in people fewer than 5%, 2 points for between 5%-10%
Question 7	Science Experiment	1 point for each item used in the experiment, for methods with scientific validity 3 points		4 points for each answer found in people fewer than 5%, 2 points for between 5%-10%
Question 8	Science Experiment	3 points for each correct experimental setup 3 points for each correct explanation		4 points for each answer found in people fewer than 5%, 2 points for between 5%-10%
Question 9	Scientific Imagination	1 point for each answer produced	1 point for each different answer proposed (1) Genetic Disease (2) Social justifications (3) Body disorders (4) Scientific work	2 points for each answer found in people fewer than 5% 1 point for 5%-10%
Question 10	Product Development	1 point for each answer produced	1 point for each different answer proposed (1) Heat energy (2) Electric energy (3) Movement energy (4) Light energy (5) Devices converting into sound energy	2 points for each answer found in people fewer than 5% 1 point for 5%-10%
Question 11	Discovering the Problem	1 point for each answer produced	1 point for each different answer proposed (1) Student count (2) Sitting order (3) Course duration (4) Security (5) Physical conditions	2 points for each answer found in people fewer than 5% 1 point for 5%-10%
Question 12	Science Experiment	1 point for each item used in the experiment, 3 points for methods with		4 points for each answer found in people fewer than

Scientific Creativity Scale Evaluation Rubric				
Questions	**Sub-content**	**Fluency Score**	**Flexibility Score**	**Specificity Score**
		scientific validity		5%, 2 points for between 5%-10%
Question 13	Scientific Imagination	1 point for each answer produced	1 point for each different answer proposed (1) Life of living things (2) Physical change (3) Ecologic balance (4) Adaptation-Evolution	2 points for each answer found in people fewer than 5% 1 point for 5%-10%

Data Analysis

Total creativity scores were calculated for 13 items that were included in the Pilot Scheme. In the light of the calculated scores, the analysis of the data was made according to the Multi-Surface Rasch Model by using the SPSS 21.0 statistical program (İlhan, 2016).The unidimensionality and local independence assumptions of the Multi-Surface Rasch Model were also tested. Exploratory Factor Analysis (EFA) was performed for the unidimensionality assumption over the averages of the scores given by the raters. Before EFA, Kaiser-Meyer-Olkin (KMO) and Bartlett tests were used to determine whether the data were suitable for factor analysis (Büyüköztürk, 2018). To determine the reliability of the scale, Cronbach's Alpha Internal Consistency Coefficient was calculated for the entire scale.

The KMO value of the draft scale was found to be .671 and the Bartlett Test value was 58.272 ($p<.001$). In this respect, it can be argued that the data were suitable for factor analysis (Büyüköztürk, 2018). According to these data, EFA was applied to the draft scale by using the Principal Components Factorization Technique along with the Loopless Method to obtain a one-dimensional structure. In the factor analysis, the results were determined according to the items with a factor load above .30 and factors with an eigenvalue greater than 1 (Tabachnic and Fidell, 2001). The questions (question 10, question 11, and question 13) that had a load value difference in two factors of an item was less than .10 were removed from the scale. The Cronbach's Alpha Internal Consistency Coefficient of the scale was found to be $\alpha = .758$. This result shows that the scale is within reliable limits.

Table 3. KMO and Bartlett Test

KMO Measure of Sampling Adequacy	0.671
Bartlett's Test of Approx. Chi-Square	58.272
Sphericity	28
Sig.	0.001

(The Factor Analysis results of the Scientific Creativity Scale (SCS) given in Appendix are given in Table 4.)

In Table 4, the load values in the first factor vary between .494- .596, the load values in the second factor vary between .531- .677, and those in the third factor vary between .562- .748. The variance values explained by each factor were 25.003% for the first factor, 15.249% for the second factor, and 13.43% for the third factor. The total variance explained by the three factors was 56.683%. According to the Multifaceted Rasch Model, it was accepted that the local independence assumption was also met when the unidimensionality assumption was met (Hambleton, Swaminathan & Rogers, 1991). In the light of these data, it can be argued that the construct validity of the scale was ensured.

Table 4. Factor Analysis Results

Questions	**Factor 1**	**Factor 2**	**Factor 3**
1	.596	-	-
2	-	-	.562
3	.509	-	-
4	.501	-	-
5	-	-	.593
6	-	.677	-
7	-	.531	-
8	.494	-	-
9	.564	-	-
10	-	-	.748
% Variance	25.003	15.249	13.430
% Cumulative Variance	25.003	40.252	56.683
Cronbach Alpha Coefficient (α) =	0.758		

Results

In the evaluation process, the frequencies of the answers were determined and tabulated to calculate the specificity scores of the answers given by the students to the Scientific Creativity Draft Scale (SCDS). The frequencies and specificity scores of the answers given to the question "What kind of vehicle would you design to go to work if there was a swamp between your workplace and your home?" are given in Table 5.

When Table 5 is examined, it is seen that among the answers given to item 1, those with the highest frequency were the "Big-wheel vehicle that reduces the pressure", "Cable car", "Flying car" and "Bridge". Since these answers could not enter the 10% response frequency out of 119 answers, they did not receive specificity points. "Wide-track vehicles", "Chemicals to dry out the swamp", "Helicopter-plane", and "Ship-boat" answers, on the other hand, were given a specificity score of 1 as they had a response frequency of 5-10% among all answers. The answers of "A sled that slide on the swamp surface", "Wide-bottomed non-sinkable shoes", "Zeppelin", "A robot with long feet", "Jumping-flying shoes", "A vehicle that can go under the swamp", "A vehicle with spider legs", "A vehicle that works on methane gas" and "A vehicle that does not sink by blowing air from the bottom" were

received 2 originality points by 5% response frequency.

Table 5. Frequencies and Specificity Scores of Answers Given to SCDS Question 1

Answers given to Question 1	**Answer Frequency**	**Specificity Point**
Big-wheel vehicle to reduce pressure	23	0
Cable car	16	0
Flying car	15	0
Bridge	13	0
A vehicle with wide tracks	11	1
Chemicals to dry out the swamp	9	1
Helicopter or airplane	7	1
Ship-boat	7	1
Sled slide on the swamp	4	2
Wide-bottomed non-sinkable base	3	2
Zeppelin	2	2
Robot with long feets	2	2
Jumping-flying shoes	2	2
A vehicle that can go under the swamp	1	2
Spider-leg vehicle (to increase surface tension)	1	2
Flying bicycle	1	2
Vehicle working on methane gas	1	2
Vehicle blowing air from below	1	2
Total	**119**	**24**

The frequencies and specificity scores of the answers given by the students to the question "Suppose that you have designed a vehicle with unlimited energy, what kind of scientific studies would you do with this vehicle?" are given in Table 6.

When Table 6 is examined, it is seen that the most common answers given by the students to question 2 were "I would go to unknown planets", "Transform them into different types of energy" and "Try to reach the speed of light". Since these answers were out of the 10% response frequency among 116 answers, they did not receive specificity points. "I would explore the undiscovered ones by traveling around the world" and "I would search if there were living beings in space" answers had 1 one specificity point because the response frequency was between 5% and 10%. Since the answers "I would research the Bing-Bang theory", "I would try to store energy", "I would use it in evolutionary research", "I would use it in health and education", "I would try to prove the theory of relativity", "I would try to solve the mystery of the black hole", "I would use it to end environmental pollution", "I would do mind-reading exercises", "I would like to go to the center of the Earth" and "I would like to build a time machine" were in the 5% response frequency, they had the specificity point of 2.

Table 6. Frequencies and Specificity Scores of the Answers Given to SCDS Question 2

Answers given to Question 2	**Answering Frequency**	**Specificity Score**
I would go to unknown planets	37	0
I would transform it into different types of energy	25	0
I would try to reach the speed of light	14	0
I used to travel the world in search of the undiscovered	10	1
I'd search if it's alive in space	8	1
I would research the Bing-Bang theory	5	2
I would try to store energy	5	2
I would use it for evolutionary research	3	2
I would use it in the fields of health and education	2	2
I would try to prove the theory of relativity	2	2
I would try to solve the mystery of the black hole	2	2
I would use it to end environmental pollution	1	2
I used to do mind-reading exercises	1	2
I would like to go to the center of the earth	1	2
I would like to make a time machine	1	2
Total	**116**	**22**

In Table 7, the frequencies and specificity scores of the answers given to the question "Suppose that your teammates forgot you on the planet during space explorations and returned to Earth, what would you do to survive?" are given.

Table 7. Frequencies and Specificity Scores of the Answers Given to SCDS Question 3

Answers given to Question 3	Answering Frequency	Specificity Score
I would look for food, water, and living beings	33	0
I used to produce food by multiplying the vegetables and fruits left in the station.	30	0
I would try to use my energy sparingly	26	0
I would try to contact my teammates or the world	20	0
I would set up a system to increase the amount of reduced oxygen	10	1
I would install a system to increase the decreasing amount of clean water	8	1
I would build a vehicle to have back to Earth	3	2
Total	**130**	**4**

When Table 7 is examined, the most common answers given to question 3 were "I would search for food, water, and living beings", "I would try to produce vegetables and fruits at the station", "I would try to use my energy

sparingly" and "I would try to contact my teammates or the world" were not given specificity score because they could not enter the 10% answering frequency. The answers "I would set up a system to increase the amount of reduced oxygen" and "I would set up a system to increase the decreasing amount of clean water" had 1 specificity point because they were in the response frequency of 5%-10%. The answer "I would build a vehicle to return to Earth" had 2 specificity points because it is included in the 5% response frequency.

The frequencies and specificity scores of the answers given to the question "How would the world be affected by this situation if the light did not propagate in space?" are given in Table 8.

Table 8. Frequencies and Specificity Scores of the Answers Given to SCDS Question 4

Answers given to Question 4	**Answering Frequency**	**Specificity Score**
The world would be dark	54	0
No life events would have happened	46	0
The world would be cold	16	0
Plants could not photosynthesize	13	1
We couldn't distinguish colors	5	2
There would be no day-night differences	4	2
The science of astronomy would not have developed	4	2
Different life forms could have formed	2	2
Eyesight could not develop	2	2
There would be no scientific advances	2	2
There would be no fertile land	1	2
Moon phases would not occur	1	2
Total	**150**	**17**

When Table 8 is examined, the answers given to question 4 "The world would be dark", "No vital events would be" and "The world would be cold" could not have a specificity score because they could not enter the 10% response frequency. The answer "Plants could not photosynthesize" had 1 specificity point because it was in the response frequency of 5-10%. The answers "We could not distinguish colors", "Day and night differences would not occur", "The science of astronomy would not develop", "Different life forms could have formed", "Eyesight could not develop", "There would be no scientific advances", "Fertile lands would not occur" and "The phases of the Moon would not occur" has 2 specificity scores as they were in 5% answering frequency.

The frequencies and specificity scores of the answers given to the question "How would you explain to your visually impaired student the outcome of the science course 'Associate the reason why objects appear black, white and colored as a result of their observations with the reflection and absorption of light'?" are mentioned in Table 9. In the fifth question, where the response frequency was quite low, fluency and specificity scoring were combined in the scoring of the answers, 1 point was given for each answer that did not have the 10% frequency, 2 points for each answer between 5% and 10%, and 4 points for each answer that had the 5% frequency. When

Table 10 is examined, the answers given to question 5 about the relief method and the answers containing the heat method received 1 point because they could not enter the 10% answering frequency. Answers that described emotions by analogy and answers that simulated white to a ball dropped on hard ground and black to a ball dropped on a sandy ground received 2 specificity points because they were in the 5%-10% response frequency. The other answers in the table, had 4 specificity points because they were in the 5% response frequency. The frequencies and specificity scores of the answers given to the question "You will explain to your students the methods of separating liquid-liquid homogeneous mixtures in the science laboratory by experimenting. However, your school does not have the necessary materials. How would you prepare an experimental setup from the materials used in daily life in order to explain the subject?" are given in Table 10.

Table 9. Frequencies and Specificity Scores of the Answers Given to SCDS Question 5

Answers given to Question 5	**Answering Frequency**	**Specificity Score**
By using the embossing method	27	1
By using the heat method	21	1
By analogy with emotion (Bad feelings black, good feelings white)	5	2
White; dropping the ball on the hard ground from high Black; dropping the ball on the sandy ground from high	5	2
Comparing white light to an echo	4	4
By analogy with the act of swallowing the color black	4	4
Comparing black to the unknown and white to the known	4	4
Black; by throwing objects on a sticky surface	3	4
Responses that change the walking speed of the individual according to the wavelength of the colors	1	4
By relating to the flavors of food	1	4
By describing the colors that make up white light by breaking glass	1	4
Comparing the black to a matryoshka doll	1	4
Total	**77**	**38**

When Table 10 is examined, the answers "I would put the alcohol-water mixture in a jar, run a hose through the hole in the lid, heat the mixture, cool the hose and condense the evaporating alcohol, heat the alcohol-water mixture in the classroom with a candle", "Heat the alcohol-water mixture in the teapot, connect a hose to the pipe of the teapot and remove it from the hose, I would condense the alcohol that passes through" did not have the 10% response frequency, they did not have specificity points. The answers "I would put the alcohol-water mixture in the pot and pull a tarp over it. After wrapping the two hoses in a spiral shape, I would add one of the hoses to the system by piercing the tarp, and I would run cold water through the other, etc." had 2 specificity points because they were in the response frequency of 5%-10%. The answer, "I would heat the alcohol-water mixture in a bowl

on which I place metal at an angle of 45o. By putting pieces of ice on the metal, the alcohol vapor that hits the metal surface condenses and accumulates in the container at the tip of the metal", had 4 specificity points because it was included in the 5% response frequency.

Table 10. Frequencies and Specificity Scores of the Answers Given to SCDS Question 6

Answers given to Question 6	**Answering Frequency**	**Specificity Score**
I would put the alcohol-water mixture in a jar, run a hose through the hole I made on the lid, heat the mixture, cool the hose, and condense the evaporating alcohol.	31	0
I would heat the alcohol-water mixture with candles in the classroom setting	26	0
I would heat the alcohol-water mixture in the teapot. I connect a hose to the pipe of the teapot and condense the alcohol that runs through the hose.	24	0
I would put the alcohol-water mixture in the pot and put a tarp on it. After wrapping the two hoses in a spiral, I add one of the hoses to the system by piercing the tarp and running cold water through the other.	6	2
I would heat the alcohol-water mixture in a bowl on which I place metal at an angle of 45^{o}. By placing pieces of ice on the metal, I allow the alcohol vapor that hits the metal surface to condense and accumulate in the container at the end of the metal.	1	4
Total	**88**	**6**

The frequencies and specificity scores of the answers given to the question "Design as many experiments as possible that will help 5th grade students to distinguish the concepts of heat and temperature?" are given in Table 11.

When Table 11 is examined, the answers given to question 7 "By heating different amounts of liquids of the same type with identical heaters for the same time", "By heating different types of liquids in the same mass with identical heaters for equal time", "By giving the same amount of heat to different types of metals and having the temperature changes calculated" and "By adding food coloring to the hot one from two liquids with different temperatures, slowly combine them in the same container and observing the heat exchange" can not get originality points since they did not included in the 10% response frequency. The answers "By putting the ice cubes in the palms of the students and talking about heat exchange when they observe the melting" and "By resembling the energy taken from buttered bread to heat, and the fact that we are active when we eat it like heat" had 4 specificity points because they were at the 5% response frequency.

Table 11. Frequencies and Specificity Scores of the Answers Given to SCDS Question 7

Answers given to Question 7	Answering Frequency	Specificity Score
By heating different amounts of liquids of the same type with identical heaters for the same time.	25	0
By heating different types of liquids in the same mass with identical heaters for an equal time.	23	0
By giving the same amount of heat to different types of metals and having the temperature changes calculated.	15	0
By adding food coloring to the hot one from two liquids with different temperatures, slowly combine them in the same container and observing the heat exchange.	10	0
By putting the ice cubes in the palms of the students and talking about heat exchange when they observe the melting.	4	4
By resembling the energy taken from buttered bread to heat, and the fact that we are active when we eat it like heat.	1	4
Total	**78**	**8**

The frequencies and specificity scores of the answers given to the question "Design as many experiments as you can by using materials such as rulers, books, pencils, chairs, desks, etc. in the classroom setting for the students who had difficulty in understanding the subject of 'gain from strength' " are given in Table 12.

Table 12. Frequencies and Specificity Scores of the Answers Given to SCDS Question 8

Answers given to Question 8	Answering Frequency	Specificity Score
I would leverage using the ruler.	46	0
I make an ordinary inclined plane.	17	0
I set up a pulley system with the patterns on which the sewing threads are wound.	4	4
I would like them to sit the same Student at the end and the middle of the row, lift and drag them like a wheelbarrow.	3	4
I used to set up a catapult system with rulers	3	4
I would like him to sharpen the tip of the pencil and dip it into the eraser, and again with the same force when the tip was broken.	2	4
Total	**75**	**16**

When Table 12 is examined, the answers given by the students to question 8 "I would leverage by using the ruler" and "I would make an ordinary inclined plane" could not have a specificity score because they could not enter the 10% answering frequency. The answers "I would set up a pulley system with the patterns on which the sewing threads are wound", "I would place the same student at the end and the middle of the row and ask them to lift and

drag like a wheelbarrow", "I would set up a catapult system with rulers" and "I would like the tip of the pencil to be sharpened and dipped into the eraser and dip it again with the same force when the tip was broken" were within 5% of the response frequency and received 4 specificity points.

The frequencies and specificity scores of the answers given by the students to the question "How will the future of humanity be affected if a hereditary disease that occurs as a result of mutation and is carried by the sex chromosomes has a dominant character?" are given in Table 13.

When Table 13 is examined, the answers given by the students to question 9 "The incidence of hereditary diseases would increase" did not have a specificity score because they did not fall within the 10% response frequency. The answers "Mental and bodily disorders would be experienced in the development of people" and "Scientific studies for treatment methods would increase" had 1 specificity point because it was in the 10% answer range. The answers "Sick people would be not allowed to reproduce", "The state would intervene in mate selection", "People's diets could change" and "Life expectancy would be shortened" were included in the 5% response frequency, and they received 2 specificity points.

Table 13. Frequencies and Specificity Scores of the Answers Given to SCDS Question 9

Answers given to Question 9	**Answering Frequency**	**Specificity Score**
The incidence of genetic diseases increases.	79	0
Mental and physical problems are experienced in the development of people.	8	1
Scientific studies for treatment methods would increase.	6	1
Sick people were not allowed to reproduce.	2	2
The state would intervene in the election of spouses.	2	2
People's diets could change.	1	2
Life expectancy would be shortened.	1	2
Total	**100**	**12**

The frequencies and specificity scores of the answers given to the question "What would you do if you were to design devices that could make your life easier with a small solar energy panel?" are given in Table 14.

When Table 14 is examined, the answers given to question 10, "I would make a charger" and "A rechargeable car" could not have specificity points because they could not enter the 10% response frequency. The answers "I would set up a heating system" and "Build a fan" were in the response frequency of 5% to 10%, and received 1 specificity point. The answers "I would meet the electricity needs of the house I lived in", "I would use it for lighting", "I would make a garbage collector", "I would make an electric bicycle", "I would use it in a watch", "I would make a heated coat", "I would use it in hearing aid", "I would make a device to absorb sound waves", "I would make an electric tractor", "I would make a window cleaning device", "I would make a calculator", "I would build a food processor" and "I would build a vacuum cleaner", on the other hand, received 2 specificity points since they were in the 5% response frequency.

Table 14. Frequencies and Specificity Scores of the Answers Given to SCDS Question 10

Answers given to Question 10	Answering Frequency	Specificity Score
I would make a charger	50	0
I would build a rechargeable car	16	0
I would install a heating system	10	1
I would make a fan	7	1
I would meet the electricity needs of my house	6	2
I would use it for enlightenment	6	2
I would make a garbage collection robot	6	2
I would make an electric bike	6	2
I would use for watch	3	2
I would make a heated coat	2	2
I would use it in hearing aid	2	2
I would make a device that absorbs sound waves	1	2
I would make an electric tractor	1	2
I would make a glass cleaner	1	2
I would make a calculator	1	2
I would make a food processor	1	2
I would make a vacuum cleaner	1	2
Total	**120**	**28**

The frequencies and specificity scores of the answers given to the question "What arrangements and changes can be made to enable students to work more comfortably and easily in physics, chemistry, and biology laboratories?" are given in Table 15.

Table 15. Frequency and Specificity Scores of the Answers Given to SCDS Question 11

Answers given to Question 11	Answering Frequency	Specificity Score
I would increase the number of materials and reduce the class size so that the students can work individually.	73	0
I used to show the stages of the experiment on the screen all the time with a smartboard or TV.	19	0
I would hang instructions on the walls outlining safety precautions.	14	1
Materials should be organized and students should have easy access.	11	1
I would design the seating arrangement so that all students see each other.	9	1
I would not lock the laboratory doors. Students should be able to study whenever they want, accompanied by an attendant.	9	1
Chairs and stools should be added for sitting.	7	2
They must be well ventilated because of the odor of chemicals	6	2
Total	**148**	**8**

When Table 15 is examined, the answers given to question 11 "I would increase the number of materials and decrease the class size so that the students could work individually" and "I would constantly show the stages of the experiment with a smartboard or TV on the screen" could not have specificity points because they were not in the 10% answer frequency. The answers "I would hang instructions on the walls outlining safety precautions", "materials should be organized, students should have easy access", "I would design the seating arrangement so that all students could see each other" and "I would not lock the laboratory doors, students should be able to study whenever they want, accompanied by an attendant" were in the 5%-10% answer frequency, they had 1 specificity point. Since the answers "Chairs and stools must be added for sitting" and "Ventilation must be good because of the odor of the chemicals" were included in the 5% response frequency, they received 2 specificity points.

The frequencies and specificity scores of the answers given to the question "How do you measure the air pressure in the indoor setting you are in by using the tools in the laboratory?" are given in Table 16.

Table 16. Frequencies and Specificity Scores of the Answers Given to SCDS Question 12

Answers given to Question 12	**Answering Frequency**	**Specificity Score**
Using a barometer by filling mercury in a measuring tape or glass tube with a closed-end and turning it upside down in the mercury-filled container.	21	0
By using a manometer.	15	0
By using a barometer	15	0
By filling mercury in a closed one-end U-tube and bringing the open end into contact with the gas in the chamber.	6	2
I would fill the beaker with water and lighting a candle on it. Than I would turn the beaker upside down so that the candle would not go out in the container filled with water and calculate the amount of water rising.	2	4
I would compare the volumes of identical balloons, inflated to the same volume, after keeping one in the open air and the other inside.	1	4
Total	**60**	**10**

When Table 16 is examined, the answers given to question 12 "By filling mercury in a closed glass pipe and turning it upside down in a container filled with mercury", "By using a barometer" and "By using a manometer" could not have a specificity score because they could not enter the 10% response frequency. The answer "By filling mercury in a closed one-end U-tube and bringing the open end into contact with the gas in the chamber" received 2 specificity points because it was at a response frequency of 5% to 10%. The answers "I would fill the beaker with water and lighting a candle on it. Than I would turn the beaker upside down so that the candle would not go out in the container filled with water and calculate the amount of water rising", and "Keep one of the identical balloons inflated at the same volume in the open air and the other inside, I would compare their volumes" were in the 5% response frequency had the specificity score of 4.

The frequencies and specificity scores of the answers given to the question "Unlike all known liquids, the volume of water decreases until it drops to a certain temperature (+4oC), then starts to increase again. How would our world be affected by this situation if water did not have this special condition?" are given in Table 17.

Table 17. Frequencies and Specificity Scores of the Answers Given to SCDS Question 13

Answers given to Question 13	**Answering Frequency**	**Specificity Score**
There would be no life underwater	58	0
The waters would start to freeze from the bottom	23	0
The temperature change in the waters would be faster	15	0
The ecological balance would be disturbed	7	1
Ice floes at the poles would not be as prominent as they are today.	6	2
Adaptation of aquatic creatures would be different	2	2
Eutrophication would increase	1	2
Considering that we came from water evolutionarily, there would be no living forms today.	1	2
Frozen bodies of water wouldn't break bottles	1	2
Total	**115**	**11**

When Table 17 is examined, the answers given to question 13 "There would be no life under water", "The waters would start to freeze from the bottom" and "The temperature change in the waters would occur faster" could not have a specificity score because they could not enter the 10% response frequency. The answer "The ecological balance would be disturbed" received 1 specificity point because it was in the frequency of 5-10%. Since the answers "The ice floes at the poles would not be as prominent as today", "The adaptation of aquatic organisms would be different", "Eutrophication would increase", "Considering that we came from water evolutionarily, there would be no living forms today" and "Frozen water bodies would not break bottles" were in 5%, they received 2 specificity points.

Discussion

When the studies conducted on scientific creativity were reviewed, it was seen that they generally aimed to measure the scientific creativity of secondary school students. The Scientific Creativity Scale, which was prepared by Hu and Adey (2002) for secondary school students, is used in studies conducted relatively less on undergraduate students. We believe that a deficiency in measuring the scientific creativity of undergraduate students at the academic level will be eliminated with the scale we developed.

The way of raising creative individuals is through the curricula and creative teachers who have activities to develop creativity. The higher the creativity of the teachers who implement the training programs, the higher the probability of raising creative individuals. For this reason, it is necessary to increase studies measuring the creativity of teacher candidates and to rearrange the undergraduate curricula in the light of these studies.

If the answers given by the students to the SCDS in the Pilot Scheme of the scientific creativity scale were examined, it was found that the answers given to the question "What kind of vehicle would you design to go to work if there was a swamp between your workplace and your home?" aimed at measuring product development levels, were the answers that people with ordinary pressure knowledge could give and tools used in daily life. When the answers that could have specificity points were examined, it was found that there were very few answers that could be called creative.

It was also found that the answers given to the question "Suppose that you designed a tool with unlimited energy, what kind of scientific studies would you do with this tool?" aimed at measuring the level of discovery of the problem by the students, were aimed at researching questions that were not yet answered by scientific studies. When the answers that could have specificity points were examined, it was seen that original ideas that seemed scientifically impossible were put forward. When the answers given to the question "During space explorations, your teammates forgot you on the planet and returned to Earth, what would you do to survive?" which aimed to measure the scientific imagination of the students, were examined, it was seen that the answers for temporary and permanent solutions were almost at the same level. When the answers that could have specificity scores were examined, it was seen that answers that could meet the basic requirements for survival were obtained.

The fourth question of the SCDS; "How would the world be affected if the light did not spread in the space?" was intended to measure the scientific imagination of students. It was seen that generally monotonous answers that an ordinary person could give and that did not include cause-effect relations were given. For example, regarding the answer "The world would be dark if the light did not spread in the space", it was seen that the response frequency was quite high, which shows that the creativity levels of the undergraduate students who gave this answer were low. When the answers that were able to have specificity points were examined, the answers that mentioned the lack of events caused by light energy were given. This shows how wide a window the students with field knowledge consider the event.

Although the response frequency of the question "How would you explain to your visually impaired student the outcome of the science course 'Associate the reason why objects appear black, white and colored as a result of their observations with the reflection and absorption of light'?" which aims to measure the creativity of the students by exploring the problem and by using their knowledge of the field and educational sciences, was low, it was seen that the answers given were quite creative. The sixth question of the SCDS; "You will explain the methods of separating liquid-liquid homogeneous mixtures to your students by experimenting in the science laboratory. However, your school does not have the necessary materials. How do you prepare an experimental setup from the materials used in daily life to explain the subject?" which aims to measure creativity in the ability to set up experiments in science. It was seen that the students could set up creative devices without being stuck with the function. This shows that students had the creativity to experiment even in schools where conditions were not good.

The answers given to "Design as many experiments as possible that will help 5th Graders to distinguish the concepts of heat and temperature?" question about setting up creative experimental setups on the subject of heat

and temperature, which is one of the subjects with the most misconceptions in secondary school students were evaluated, it was seen that there were known examples in general. This shows that our pre-service teachers could not be creative on this issue where students have misconceptions. Considering the answers not included in the scoring, it was seen that the misconception continued at the undergraduate level. Since our study intended scale development, the answers that were not scored were not given in a table.

The eighth question was intended to explain the subject of gaining strength in simple machines to the students, it was aimed to prepare a creative experimental setting with the materials provided. When the answers given to the question "Design as many experiments as you can by using materials such as rulers, books, pencils, chairs, desks, etc. in the classroom setting for the students who had difficulty in understanding the subject of 'gain from strength' " were examined, it was seen that the answering frequency was very low and the students were content with one single mechanism. This shows that the creativity of our students was low in this regard.

The question "How would the future of humanity be affected if a hereditary disease emerging as a result of mutation carried with sex chromosomes had a dominant character?" was aimed to measure the creativity of students by showing their scientific imagination, the expected result of the question was that the rate of hereditary diseases would increase. It can be argued that the creativity of the students who gave this answer was low. The answers with specificity scores were creative answers that may not come to the mind of ordinary people and that may become scientific and state policy. It was aimed at measuring the creativity of students in product development by "What would you do if you were asked to design devices that could make your life easier with a small solar energy panel?" It was seen that the created products were used in daily life, so the creativity of the students was low in this respect.

The 11th question "What arrangements and changes can be made to enable students to work more comfortably and easily in physics, chemistry, and biology laboratories?" was about exploring the problem, it can be argued that they gave creative answers considering the difficulties they experienced in the laboratory studies, which shows that one of the most important factors of creativity is the needs of the individual.

The answers given to the 12th question; "How do you measure the air pressure in an indoor setting by using the tools in the laboratory?" which was aimed at revealing the creativity of the students in creating a science experiment, were examined and it was seen that the frequency of the answers "By using ready-made materials such as barometer and manometer" was high. Such answers show that the creativity of students is low. The answers with specificity scores are the creative ones. When the answers given to the question "Unlike all known liquids, the volume of water decreases until it drops to a certain temperature (+4oC), then begins to increase again. How would our world be affected by this if this special condition of water did not exist?" were evaluated, and it was seen that very creative answers were given.

Trentham (1975) reported that students are highly affected by distracting factors and time in creativity tests. We can attribute the low frequency of answering the last questions and the low level of creativity in the Pilot Scheme to the length of the test. When the answers given to the test were examined, we saw that the response frequencies

of the 5th, 7th, 8th, and 12th questions were very low. When it is considered that these questions are complex at the level of constructing science experiment and the length of the test, the students may not be bored and not show their creativity.

At the end of the Pilot Scheme, questions 10, 11, and 13 in the draft scale were removed because the difference in load values in the two factors was less than .10. The final scientific creativity scale with 10-question, had 3 factors; Factor 1 consisted of 5 questions (questions 1, 3, 4, 8, and 9), Factor 2 consisted of 2 questions (questions 6 and 7), and Factor 3 consisted of 3 questions (questions 2, 5, and 10). Load values in the first factor varied between .494 and .596. The load values of the second factor were .531 and .677. The load values of the third factor varied between .562 and .748, which shows that the scale is reliable.

Conclusion

In 21st century education, as critical thinking, problem solving, communication and collaboration also the creativity is a key competence (Timotheou & Ioannou, 2021). So when we think that scientific creativity can be developed from an early age, free spaces must be created for students to express their ideas, and educational areas must be adapted to this by supporting extraordinary thoughts. The setting needed for the development of creative thinking skills is a non-traditional classroom setting where children can express their feelings and thoughts freely. The educational setting must be the one where students feel free. Students must also be able to express their ideas easily (Öztürk, 2001). The biggest task in this respect falls to science teachers. Teachers must also support the ideas that contradict the logic and must not criticize the students for these ideas and encourage them. They must provide a setting where students can express their thoughts at every opportunity. In this content, first of all, it is necessary to raise awareness of the importance of creativity in science teachers. Determining the creativity levels of teachers and teacher candidates and provide training to improve their creative thinking skills can be one of the important steps on this path. In order to encourage the scientific creativity of students, it is important and necessary for teacher candidates to be trained in an educational setting where different ideas are valued and creative thoughts are encouraged. In this regard, pre-service teachers studying at the undergraduate level should be supported to develop solutions to the problems they face in daily life and should be freed in the laboratory setting. The training provided to teacher candidates must be practical rather than theoretical. Creative activities have to be included more in the content of the courses for material development at the undergraduate level.

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Author Information

Hamza Erdem Şişman
https://orcid.org/0000-0001-6445-9222
Ministry of Education
Science and Arts Education Center, Malatya
Turkey
Contact e-mail: *erdemsisman88@gmail.com*

Nilay Aydoğan
https://orcid.org/0000-0002-5510-7804
Inonu University
Faculty of Education, Malatya
Turkey

Özlem Çankaya
https://orcid.org/0000-0002-7407-2352
Inonu University
Faculty of Education, Malatya
Turkey

Appendix.

SCİENTİFİC CREATİVİTY SCALE

Name-Surname (Optional):

Age: **Gender:** **Grade:**

Dear participants, this scale offers you the opportunity to solve problems, generate new ideas and demonstrate your scientific creativity. Please express your ideas and solutions without hesitation. We expect you to complete the questions on the scale in approximately 50 minutes. Thank you for your participation.

Questions

1) What kind of vehicle would you design to go to work if there was a swamp between your workplace and your home?

2) Suppose that you have designed a vehicle with unlimited energy, what kind of scientific studies would you do with this vehicle?

3) Suppose that your teammates forgot you on the planet during space explorations and returned to Earth, what would you do to survive?

4) How would the world be affected by this situation if the light did not propagate in space?

5) How would you explain to your visually impaired student the outcome of the science course "Associate the reason why objects appear black, white and colored as a result of their observations with the reflection and absorption of light"?

6) You will explain to your students the methods of separating liquid-liquid homogeneous mixtures in the science laboratory by experimenting. However, your school does not have the necessary materials. How would you prepare an experimental setup from the materials used in daily life in order to explain **the subject?**

7) Design as many experiments as possible that will help 5th grade students to distinguish the concepts of heat and temperature?

8) Design as many experiments as you can by using materials such as rulers, books, pencils, chairs, desks, etc. in the classroom setting for the students who had difficulty in understanding the subject of "gain from strength".

9) How will the future of humanity be affected if a hereditary disease that occurs as a result of mutation and is carried by the sex chromosomes has a dominant character?

10) How do you measure the air pressure in the indoor setting you are in by using the tools in the laboratory?