

STUDENT, PARENT AND TEACHER PERCEPTIONS ON THE BEHAVIORAL CHARACTERISTICS OF SCIENTIFIC CREATIVITY AND THE IMPLICATIONS TO ENHANCE STUDENTS' SCIENTIFIC CREATIVITY

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Introduction

There are many aspects to consider for the scientific creativity of students, including cognitive, affective, attitude, and environmental influences. Of these, this research focuses on the environmental aspects that encourage scientific creativity. Since parents' and teachers' perception of scientific creativity are parts of this environmental aspect, this research has examined their perceptions on scientific creativity.

Many studies have emphasized the importance of the right environment to encourage creativity¹ (Cole et al., 1999; Csikszentmihalyi, 1996; Peter-Szarka, 2012; Sternberg & O'hara, 1999). For instance, Davies et al. (2013) conducted a literature review and summarized the conditions needed to encourage creativity with eight items, such as the availability of appropriate materials, work outside the classroom/school, opportunities for peer collaboration, and so on. In more detail, de Souza Fleith (2000) proposed a classroom environment that enhances creativity with 16 items in four categories: teachers' attitudes, strategies, activities and educational system. Richardson and Mishra (2018) developed practical guidelines to build a creative learning environment consisting of 14 items in three categories: physical environment, learning climate and learner engagement. These environmental conditions that have been suggested for creativity include a need for the teacher to properly understand creativity. For example, teachers should be able to accept new ideas, support taking risks in the classroom (Richardson & Mishra, 2018), and provide flexible directions and open-ended activities (de Souza Fleith, 2000). Beghetto and Kaufman (2014) also discussed what teachers should understand about creativity and what efforts should be made to develop students' creativity.

¹ In this paper, general creativity is written as just 'creativity', and it is written as 'scientific creativity' only in the case of scientific creativity.



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Abstract. *Teachers' and parents' perceptions of scientific creativity are assumed to be an important environmental factor for scientific creativity, so this research surveyed their perceptions of the behavioral characteristics of scientific creativity and compared their perceptions to those of students. This is achieved with a list of behavioral characteristics of creative physicists during their growth period. For this survey, 48 science teachers, 112 parents, and 145 science gifted students participated. Out of the 30 items of the list, they selected 10 items that were considered important indicators to become creative scientists in the future, and they ranked them according to their importance. The results showed that the three groups all perceived 'conducting experiments, asking questions, thinking logically to solve difficult problems, and sharing ideas' as important for scientific creativity. For the items that were perceived to be less important, it was discussed why these items might be necessary for scientific creativity. Comparative result showed that parents gave more importance to learning-related aspects, teachers to thinking-related aspects, and students to activities such as making and experimenting. This research showed the behavioral characteristics that should be encouraged to improve students' scientific creativity at school and at home.*

Keywords: *behavioral characteristics, creativity perception, creative environment, scientific creativity*

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This research started with the assumption that the perception or awareness of scientific creativity by teachers, parents and students plays an important role as an environment to encourage and guide the students' scientific creativity.

One interesting feature found in research of how teachers, parents, and students perceive creativity is that there are often some misconceptions of creativity. According to Guncer and Oral (1993), students considered non-compliant by Turkish teachers showed higher score on the TTCT creativity test, and Aljughaiman and Mueller-Reynolds (2005) also said that students with tendencies that teachers disliked were often highly creative students. Fryer and Collings (1991) noted that 70% of surveyed teachers in England and Wales regarded creativity as a rare talent, and Jaba et al. (2009) also found that only 14% of surveyed college students saw creativity as a characteristic that everyone had, and 78% of the students saw it as a characteristic that only a few had. Gralewski and Karwowski (2018) said that some teachers perceived creative students as students who were self-controlled and disciplined, not as students who could solve inventive or open problems well. Diakidoy and Kanari (1999) reported that student-teachers believed creativity was only found in the arts, and creative products were new but not necessarily appropriate or right. Aljughaiman and Mowrer-Reynolds (2005) also said that only 15% of the teachers correlated divergent thinking with creativity. These findings indicate that people's perceptions of creativity may differ from those of experts.

Similarly, perceptions of the behavioral characteristics of scientific creativity may vary among teachers, parents and students, and this difference in perception may serve as a hindrance to fostering students' scientific creativity. For example, if students think that activities such as 'making' are important for scientific creativity, but teachers and parents think those activities are not very important, then the 'making' that students want to do may not be supported by their teachers or parents.

Research Aim

The basic aim of this research is to examine and compare the perceptions of the behavioral characteristics of scientific creativity by three groups: teachers, parents and students. The behavioral characteristics that are used are obtained from a list of the behavioral characteristics of creative physicists (BCCP) developed by Shin and Park (2020). This list consists of 30 items across eight categories, it is based on the actual behavioral instances of six physicists during their growth period, and it showed a high reliability and validity by applying it to scientifically gifted upper secondary school students. This list was developed based on the behavioral characteristics shown by creative physicists in their childhoods, and it described observable behavioral characteristics. Therefore, it was expected for parents, students, and teachers to be able to use the list easily to identify the behavioral characteristics of students. The detailed aims of this research are:

- To highlight the BCCP items that teachers, parents and students consider important.
- To analyze the differences in the perception of behavioral characteristics of scientific creativity among teachers, parents and students.
- To discuss the perceptions that teachers and parents may need to change in order to encourage students' scientific creativity.

Research Background

While this research is about scientific creativity, previous findings on general creativity can also provide meaningful implications. Research which examined teachers' recognition of creativity (e.g., Berezki & Karpati, 2018) can be classified into three categories: perceptions of the nature of creativity, perceptions of the characteristics of creative students and perceptions of the creative learning environment (Andiliou & Murphy, 2010).

First, regarding research on teachers' perceptions of the nature of creativity, Fryer and Collings (1991) conducted a survey of 1,028 teachers in England and Wales and reported that teachers perceived creativity as imagination, original ideas, self-expression, and so on, and about 71% of teachers considered creativity as a 'rare gift'. Aljughaiman and Mowrer-Reynolds (2005) found that 88% of American teachers they surveyed associated creativity with original ideas. Liu and Lin (2014) noted that the perception of scientific creativity from Taiwanese teachers could be put into three categories: divergent thinking (e.g., innovation and imaginative), autonomy (e.g., adventurous and/or non-conforming), as well as curiosity and interest.

Second, regarding research on teachers' perceptions of the characteristics of creative students, Aljughaiman



and Mowrer-Reynolds (2005) reported 92% of respondents said creative students had the characteristic of thinking differently from others. Hoff and Carlsson (2011) found that teachers thought creative students also had other characteristics, such as high levels of academic achievement, ability for cooperation, psychological well-being and self-confidence. Karwowski (2010), who surveyed 630 teachers in Poland, said that teachers thought creative students were more dynamic, intellectual, and excitable, but on the other hand they were also perceived to be less agreeable and conscientious. Chan and Chan (1999) found that teachers in Hong Kong thought that creative students asked a lot of questions, were imaginative, responsive, active, and had a high intellect.

Finally, according to research that examined teachers' perception of a creative learning environment, 80% of American teachers surveyed thought that creativity could be developed in school classrooms (Aljughaiman & Mowrer-Reynolds, 2005). When Rubenstein et al. (2018) asked teachers what interfered with students' creativity, 60% of the teachers' responses were about external regulations, such as limited time, exams or standardized curricula, 23% were about student characteristics, such as students not taking risks. Hartley and Plucker (2014) reported that Chinese teachers believed that even routine classroom activities, such as group discussion or watching educational movies, could improve students' creativity, and only 8% of them answered that multiple-choice tests were not suitable to foster creativity.

Parents' perceptions of creativity alongside teachers' perceptions are important to create an environment in which creativity can flourish (Walberg, 1988). Among few studies examined how parents perceive creativity, Singh (1987) surveyed 260 Indian parents the relative importance of the personality traits of creative children and found that parents did not prefer creative traits such as independent thinking and judgment, risk taking, and intuition. Runco, Johnson and Bear (1993) had 16 teachers who were not parents and 29 parents who were not teachers choose adjectives describing creative children. The result shows that 67% of the adjectives chosen by both groups were identical, while the remaining 33% were chosen by only one of the groups, and this shows that there is a difference in the perceptions created by the contrasting experiences of the two groups.

Students' perceptions of creativity alongside teachers' and parents' perceptions are also important to create a suitable environment for creativity. Jaba et al. (2009) conducted a research of 158 Romanian college students and reported that students thought of creativity as solving problems in an original way, having many ideas, performing in a different way from others, making associations between seemingly different things, and so on, so we can expect that students interested in developing creativity will consider some of these factors. Also, from students' own assessments of creativity, we can learn about their perceptions of creativity. For example, Kreidler and Casakin (2009) gave students the task of designing a small art museum and allowed them to evaluate whether their designs were creative by themselves. The result showed that their evaluations of fluency, flexibility, and overall creativity were consistent with expert's evaluation. However, when Althuizen et al. (2010) compared the results of a creative self-assessment for 120 Dutch university and graduate students with the results of a general creativity test for them, there was only a low correlation ($\alpha=0.25$) in originality and no correlation in the rest of the items of creativity. Thus, in science, too, if students don't recognize their scientific creativity correctly, they may not be able to make correct efforts for the aspects of scientific creativity that should be developed.

As noted in previous literature reviews, there are many aspects to the perception of creativity, such as perceptions of the nature of creativity, perceptions of creative students or creative teachers, and the perception of creative learning environments or creative learning strategies (Andiliou & Murphy, 2010).

This research examined the behavioral characteristics of scientific creativity that are evaluated by teachers, parents, and students as an important aspect for scientifically creative students. With the assumption that these perceptions are important to foster students' scientific creativity, this research is meaningful in that fostering students' scientific creativity is one of the important goals of science education.

Research Methodology

General Background

This research implemented a survey to collect data systematically on people's preferences, thoughts and behaviors. The questionnaire for the survey was developed using a list of behavioral characteristics of creative physicists (BCCP) during their growth period (Shin & Park, 2020). A total of 305 participants who answered the questionnaire were randomly selected among teachers, parents and students related to gifted science education in Korea. When respondents participated in a university program related to gifted science education between



July and August 2019, they responded directly to the questionnaire on site. At that time, they chose 10 items from the BCCP list that they thought were important for students to become creative scientists in the future, and they ranked the selected items according to their level of importance. Their responses were quantitatively analyzed using a statistical analysis to compare the differences between the three groups. The results were used to discuss the behavioral characteristics parents and teachers should be concerned or interested in to encourage students' scientific creativity.

Participants

In Korea, there are many centers for the gifted in science and mathematics. The center at Chungbuk National University selects gifted students in the area of science and mathematics from elementary and middle schools, and it then teaches them for about 100 hours a year. After a year of education, students who show excellent results can receive two more years of education. Of the 160 first-year students at the center, 149 students were randomly selected and agreed to participate in the survey. They responded to a questionnaire for about 20 minutes when they participated in the university-provided education program.

Among the parents of the gifted science students in the center, 116 parents expressed their intention to participate in the survey. They answered a questionnaire when they participated in a presentation in which their children presented the results of the gifted education program.

The university to which the center belongs provided an in-service training program for science teachers for gifted education in science. Among 191 science teachers that participated in the training program, 50 lower and upper secondary school teachers expressed their willingness to answer the questionnaire. They have experience teaching gifted students in science or are highly interested in gifted education in science, with an average educational background of 5.3 years.

Of the total 315 participants, 145 students, 112 parents and 48 teachers were included in the actual analysis, excluding those who responded insincerely or omitted some responses in the survey. In general, to conduct a statistical analysis, larger sample sizes are better. In a real situation, however, using the appropriate sample sizes is also recommended. For example, according to Karada and Akta (2012), for an ANOVA analysis with 95% power, $\alpha=0.05$, and an effect size $f=0.4$, the estimated sample size for the three groups is 102, which is 34 per group. Since the smallest teacher group's sample size is 48, which is larger than 34, the size of three samples in this research was judged to be sufficient for an ANOVA analysis.

Questionnaire

The behavioral characteristics of scientific creativity that teachers, parents, and students consider important to become creative scientists is obtained from a list of behavioral characteristics of creative physicists during their growth period (BCCP) (Shin & Park, 2020). The BCCP list was developed by extracting key behavioral characteristics from the literature describing various episodes during the growth period of six creative physicists: Newton, Faraday, Maxwell, Einstein, Heisenberg and Feynman. The BCCP list consists of 8 categories and 30 statements (items), as shown in Table 1.

Table 1
The BCCP list (Shin & Park, 2020)

Category	Code	Statement
I. Making	I.1	I like to make things.
	I.2	I make things using what is available nearby.
	I.3	I am used to using a machine or a device.
	I.4	I have experience making new things or devices.
	I.5	I make something complicated and accurate.



Category	Code	Statement
II. Inquiry/ Experiment	II.1	I like experiment/inquiry and do it a lot.
	II.2	I have an experimental environment and have my own laboratory space.
	II.3	I do scientific inquiry using what is available nearby.
	II.4	I plan and make scientific inquiry deliberately and meticulously.
	II.5	I do not hurry scientific inquiry
III. Task commitment	III.1	I prefer to learn by myself.
	III.2	I like to solve difficult problems.
	III.3	I have concentration.
	III.4	I have experiences of solving problems by applying effort over a long time.
	III.5	I have my own rules/standards and hate to lose.
IV. Curiosity/ Question	IV.1	I am curious about natural phenomena.
	IV.2	I enjoy thinking deeply about natural phenomena.
	IV.3	I am interested in profound/fundamental problems such as religion or philosophy.
	IV.4	I like questions and ask many questions.
V. Reading/ Summary	V.1	I do a lot of reading.
	V.2	I summarize my reading, exploring, studying and thinking.
	V.3	I have a habit of taking notes in everyday life.
VI. Logic/ Insight	VI.1	I prefer logical thinking.
	VI.2	I understand content easily (grasp the point well/have insight).
	VI.3	I use/develop my own unusual methods.
VII. Artistic interest/ expression	VII.1	I have a talent and interest in music.
	VII.2	I like poetry and am good at poetic expression.
	VII.3	I understand or express things using visualization instead of words.
VIII. Communication	VIII.1	I prefer discussion and debate.
	VIII.2	I like to share ideas with a team.

This list has gained high validity based on a survey of experts and science teachers who had experience in gifted education, and it was found to have high reliability by applying it to science upper secondary school students who showed high interest and achievements in science and mathematics using the Cronbach alpha, Cohen's kappa, and correlations between two evaluators (Shin & Park, 2020).

The reasons why this list is chosen here is because it consists of statements describing behavioral characteristics that can be easily observed by teachers, parents and students, and also because the list is appropriate to judge students' behaviors since it was developed based on actual behavioral episodes shown in the period of childhood, not on the behavior of adults.

The questionnaire provided a list of 30 items of the BCCP and asked the participants to select 10 items that they thought were important to become creative scientists, and to rank the 10 selected items from the 1st to 10th according to their level of importance.

Some of the items in the list were modified and presented as more easily understandable expressions for young students or parents. For example, item VI.1 "I prefer logical thinking" was modified to "I like logical thinking", and item VI.2 "I understand content easily (grasp the point well/have insight)" was modified to "I understand content easily and can grasp the point well".

The BCCP list was developed by looking at six creative physicists, but this research introduced the items simply as behavioral characteristics of creative 'scientists' because the subjects included young students, and as such, the general expression 'scientists' was considered appropriate rather than giving detailed expressions such as 'physicists' that could be misunderstood. Of course, the limitations of this research in this regard are discussed in the Conclusions and Implications section.



Data Analysis

The rankings of the items selected by the respondents were converted into scores. That is, 10 scores were given to the first ranked item, 9 scores were given to the second ranked item, and so on, until 1 score was given to the 10th ranked item. Using the converted scores, the total scores and the average values were obtained for each of the three groups of teachers, parents and students, and for each of the 30 items and 8 categories in the BCCP list itself.

A one-way ANOVA was conducted to determine whether there were significant differences between the average of each group, each item, and each category. When a significant difference was detected, a Scheffé analysis was conducted as a Post-Hoc test. To do this, the SPSS statistics program (version 25) was used.

Research Results*Comparison of the Eight Categories*

Table 2 shows the results of averaging the importance perceived by the groups of students, parents and teachers for each category of the BCCP.

Table 2
Three Groups' Perceptions of the Importance of Each Category of the BCCP

Category	Group						ANOVA		Scheffé test
	S: Students (n=145)		P: Parents (n=112)		T: Teachers (n=48)		F	p	
	M	SD	M	SD	M	SD			
I. Making	1.33	1.35	0.77	1.07	0.79	0.93	8.186	< .001**	S > P**, S > T*
II. Inquiry/Experiment	2.27	1.29	1.51	1.16	1.55	1.14	14.057	< .001**	S > P**, S > T**
III. Task commitment	2.40	1.36	2.89	1.52	2.30	1.50	4.516	.012*	S < P*
IV. Curiosity/Question	1.69	1.58	2.16	1.70	3.78	1.84	28.260	< .001**	S < T**, P < T**
V. Reading/Summary	2.29	1.94	2.69	1.94	1.46	1.83	6.889	.001**	S > T*, P > T**
VI. Logic/Insight	2.09	1.87	2.30	1.66	2.32	1.67	0.584	.558	-
VII. Artistic interest/expression	0.17	0.63	0.49	0.94	0.17	0.46	6.696	.001**	S < P**, P > T*
VIII. Communication	2.30	2.34	2.04	2.31	2.42	2.27	0.604	.547	-

* $p < .05$, ** $p < .01$

Looking at Table 2, we can see that categories VI (Logic/Insight) and VIII (Communication) do not show any significant differences in the importance perceived by the three groups. Since the average score for the importance of each group in both categories was higher than the overall average of 1.84 (2.09–2.32 scores for category VI and 2.04–2.42 scores for category VIII), this means that all three groups recognized that both categories were important.

There are six categories with different scores in the three groups' perceptions of importance. Among them, for category I (Making) and II (Inquiry/Experiment), students perceived these as more important than parents and teachers both, and for category V (Reading/Summary), students considered this more important than teachers. However, the recognition of importance for category I (Making) was lower (0.77–1.33 scores) than the overall mean of 1.84.

On the other hand, parents or teachers gave a higher importance to category III, IV and VII compared to students. That is, compared to students, categories III (Task commitment) and VII (Artistic interest/expression) were perceived by parents as more important, and category IV (Curiosity/Question) was perceived by teachers as more important.

There were three categories where the perceptions of the importance of parents and teachers differed. That is, category IV (Curiosity/Question) was perceived to be more important to teachers, while categories V (Reading/Summary) and VII (Artistic interest/expression) were perceived as more important to parents. However, category VII was very low in importance for all three groups (0.17–0.49 scores).



The following is a summary of the features analyzed above:

- Students, parents and teachers all value 'thinking logically' and 'communicating with others' as creative behaviors.
- There are differences between groups, but all three groups consider 'making' and 'artistic expression' to be relatively less important.
- Students think 'active characteristics (i.e., making, inquiry/experiment)' and 'reading/summary' are more important than their parents and/or teachers. However, for the aspects related to 'learning (i.e., task commitment)' and 'thinking (i.e., curiosity/question)' and 'artistic expression', teachers or parents consider it more important than students.
- When comparing perceptions of parents to those of teachers, teachers value 'aspect related to thinking (i.e., curiosity/question)' more than parents, but parents think 'learning aspect (i.e., reading/summary)' and 'artistic expression' are more important than teachers.

Comparison of the 30 Statements (Items)

The BCCP list consists of 8 categories and 30 statements (Table 1). Table 3 shows the results of a comparison between the three groups' perceptions about the importance of each statement in the BCCP list.

Table 3
Three Groups' Perceptions of the Importance of Each Statement in the BCCP

Category and Statement	Group						ANOVA		Scheffé test	
	S: Students (n=145)		P: Parents (n=112)		T: Teachers (n=48)		F	p		
	M	SD	M	SD	M	SD				
I. Making	I.1	2.67	3.69	1.29	2.55	1.06	2.35	8.303	< .001**	S > P**, S > T**
	I.2	0.82	2.13	1.09	2.20	0.81	1.93	0.576	.563	-
	I.3	1.23	2.49	0.36	1.35	0.88	1.68	5.898	.003**	S > P**
	I.4	0.96	2.26	0.98	2.28	0.98	2.01	0.004	.996	-
	I.5	0.97	2.32	0.13	0.69	0.21	0.94	8.681	< .001**	S > P**, S > T*
II. Inquiry/Experiment	II.1	4.77	3.84	3.68	3.36	4.13	3.95	2.784	.063	-
	II.2	0.64	1.72	0.08	0.59	0.06	0.43	7.769	.001**	S > P**, S > T**
	II.3	1.30	2.35	1.29	2.39	1.04	1.95	0.247	.781	-
	II.4	3.32	3.53	1.91	2.92	1.75	2.76	7.974	< .001**	S > P**, S > T*
	II.5	1.30	2.62	0.61	1.75	0.79	1.71	3.257	.040*	S > P*
III. Task commitment	III.1	2.12	2.97	3.93	3.61	1.83	3.17	11.954	< .001**	S < P**, P > T**
	III.2	2.21	3.22	2.57	3.37	2.54	3.35	0.444	.642	-
	III.3	5.74	3.72	4.43	3.77	3.88	3.56	6.359	.002**	S > P*, S > T*
	III.4	1.23	2.45	2.90	3.48	2.83	3.66	10.981	< .001**	S < P**, S < T**
	III.5	0.71	1.91	0.60	1.80	0.40	1.76	0.534	.587	-
IV. Curiosity/Question	IV.1	1.88	3.10	3.13	3.89	5.60	4.16	19.848	< .001**	S < P*, S < T**, P < T**
	IV.2	0.92	2.22	1.82	3.18	4.88	4.19	32.18	< .001**	S < T**, P < T**
	IV.3	0.22	1.19	0.35	1.43	0.50	1.79	0.791	.454	-
	IV.4	3.76	3.81	3.34	3.86	4.15	3.59	0.841	.432	-
V. Reading/Summary	V.1	3.98	3.69	4.29	4.04	2.08	3.18	6.125	.002*	S > T*, P > T**
	V.2	1.82	2.98	3.13	3.79	1.38	2.72	7.077	.001*	S < P**, P > T**
	V.3	1.08	2.44	0.66	2.05	0.94	2.20	1.105	.333	-



Category and Statement		Group						ANOVA		Scheffé test
		S: Students (n=145)		P: Parents (n=112)		T: Teachers (n=48)		F	p	
		M	SD	M	SD	M	SD			
VI. Logic/Insight	VI.1	2.78	3.37	2.62	3.48	2.79	3.38	0.085	.919	-
	VI.2	1.66	2.82	2.79	3.51	2.29	3.25	4.16	.017*	S < P*
	VI.3	1.83	2.98	1.50	2.64	1.88	3.10	0.512	.600	-
VII. Artistic interest/expression	VII.1	0.16	0.95	0.31	0.98	0.10	0.47	1.286	.278	-
	VII.2	0.06	0.59	0.09	0.59	0.00	0.00	0.463	.630	-
	VII.3	0.28	1.18	1.06	2.30	0.40	1.33	7.017	.001*	S < P**
VIII. Communication	VIII.1	2.24	3.02	1.68	2.75	1.50	2.70	1.814	.165	-
	VIII.2	2.35	3.36	2.39	3.08	3.33	3.14	1.811	.165	-

* $p < .05$, ** $p < .01$

According to Table 3, fifteen statements (statement numbers I.2, I.4, II.1, II.3, III.2, III.5, IV.3, IV.4, V.3, VI.1, VI.3, VII.1, VII.2, VIII.1 and VIII.2) do not show any significant difference between the three groups' perceptions of their importance to scientific creativity. Among these, three groups perceived statements II.1 (many inquiry/experiment, average scores are 3.68-4.77), III.2 (solving difficult problems, average scores are 2.21-3.37), IV.4 (many questions, average scores are 3.34-4.15), VI.1 (logical thinking, average scores are 2.62-2.79) and VIII.2 (sharing ideas, average scores are 2.35-3.33) as more important than the overall average of 1.84.

Among statements showing no differences, statements VI.3 (developing unusual methods) and VIII.1 (discussion and debate) showed values near the average (1.84), but the of rest the statements (I.2; making using what is available nearby, I.4; making new things, II.3; experimenting using what is available nearby, III.5; developing my own standards, IV.3; interest in fundamental problems, V.3; taking notes, VII.1; talent in music and VII.2; interest in poetry) were below the average importance value of 1.84. Therefore, the following is a summary of the statements that do not differ in perception between the three groups:

- The three groups all perceived 'conducting many experiments, asking many questions, thinking logically to solve difficult problems, and sharing ideas' as important for scientific creativity.
- The three groups all considered 'discussion/debate with their own unusual methods' as averagely important.
- Three groups all perceived 'using what is available nearby to experiment or make something new, taking notes with interest in fundamental problems, developing their own standards, and talent/interest in aesthetic aspects (poetry and music)' as less important compared to other statements in the BCCP list.

When comparing the perceptions of teachers or parents with that of students in Table 3, fifteen among thirty statements showed differences.

First, the statements that students consider more important than their parents and/or teachers are statement I.1 (like making), I.3 (using machine or device when making), I.5 (making something complicated and accurate), II.2 (having my own laboratory space), II.4 (conducting inquiry deliberately and meticulously), II.5 (conducting inquiry without hurry), III.3 (concentrating) and V.1 (reading a lot).

Among these eight statements, six statements are from category I (Making) and II (Inquiry/Experiment), and students' perceptions about four particular statements, I.1 (like making, average score is 2.67), II.4 (conducting inquiry deliberately and meticulously, average score is 3.32), III.3 (concentrating, average score is 5.74) and V.1 (reading a lot, average score is 3.98), are especially higher than the average value of 1.84.

Second, teachers or/and parents perceived the following statements to be more important compared to students: statement III.1 (learning by myself), III.4 (giving effort for a long time to solve problems), IV.1 (curiosity), IV.2 (deep thinking), V.2 (summarizing), VI.2 (grasping the point), and VII.3 (visualizing of understanding).

Of these seven statements that teachers or parents considered important compared to students, teachers



and parents both perceived the statement III.4 (giving effort for a long time to solve problems) and IV.1 (curiosity) as more important than students. And the statement that the teacher perceived as more important than students was statement IV.2 (deep thinking), and the statements that the parent considered as more important than students were statement III. 1 (learning by myself), V.2 (summarizing), VI.2 (grasping the point) and VII.3 (visualizing of understanding). Therefore, statements showing a difference between student's perception and teachers' or parents' perceptions can be summarized as follows:

- Students consider '*reading a lot and making or experimenting accurately and deliberately using machines or devices without hurrying but with concentration in their own laboratory space*' more important compared to their teachers or/and parents.
- Parents and teachers both perceive '*giving effort for a long time to solve problems and showing curiosity*' more important than students.
- Especially teachers consider '*deep thinking*' a more important behavior compared to students.
- And parents perceive '*summarizing and visualizing that they grasp the point of what they learned by themselves*' to be more important than students.

As shown in Table 3, the following five statements show differences between parents' and teachers' perceptions: III.1, IV.1, IV.2, V.1 and V.2.

That is, parents consider statement III.1 (learning by myself), V.1 (reading a lot), and V.2 (summarizing) more important than teachers, and teachers perceive statement IV.1 (curiosity), IV.2 (deep thinking) more important than parents. Therefore, this feature can be summarized as follows:

- Parents think the learning aspects (i.e. *summarizing what students learn by themselves and reading many books*) are more important than teachers, on the other hand, teachers perceive thinking aspects (i.e. *deep thinking with curiosity*) to be more important than parents.

Discussion

Of the 30 statements in the BCCP list, the three groups all perceived '*conducting many experiments, asking many questions, thinking logically to solve difficult problems, and sharing ideas*' as important for scientific creativity.

However, eight statements (*using what is available nearby to experiment or make something new, taking notes with interest in fundamental problems, developing their own standards, and talent/interest in poetry and music*) were considered less important than the average value for all three groups.

This result indicates that more attention is necessary to encourage these behavioral characteristics, which were considered less important, for scientific creativity in schools and home. For example, '*using what is available nearby to experiment to make something new*' means that experiments whose methods, tools and results are not prepared in advance are meaningful. In fact, school experiments provide experimental settings, tools and methods designed to reduce errors as much as possible and to obtain the expected clear results. Therefore, even students who have talent and interest in science have very few opportunities to conduct unprepared open experiments in schools. As a result, when teaching students in a scientifically gifted center in a university, it has been observed that many students have a lot of trouble conducting open inquiry. According to actual research procedures of real scientists, they go through cyclic or non-linear procedures when conducting research (Park et al., 2009). That is, scientists often go back to the previous stage of research, change their tentative hypotheses, obtain data repeatedly, and modify their research methods when results are not as expected, or they feel there are problems. In this approach, there is also a non-linear process for missing certain steps or changing the path of the research. Regarding this, Zion et al. (2004) observed that open inquiry could help students realize that the inquiry process was not linear but was subject to change.

In addition, '*developing their own standards*' is closely related to the aspect discussed above because this feature appears in situations in which a pre-determined process and result are ignored. This approach also emphasizes '*unusual thinking*' in creative endeavors (Park, 2004). According to the behavioral characteristics of creative physicists in their growth period, Maxwell ignored formality when developing his own rules and procedures (Cropper, 2001/2007, p. 62), Feynman calculated it in his own original way, not just following prescribed methods of calculation (Gleik, 2011, pp. 42-43), Einstein also proved the Pythagorean theorem in his own original way (Issacson, 2007, p. 17).



'*Interest in fundamental issues*' also relates to the aspects mentioned above in terms of the fact that fundamental problems do not have pre-determined or typical solutions. In fact, Heisenberg (Hermann, 1976, p. 11), Newton (Christianson, 1996, p. 22; Gleik, 2007, p. 25), and Einstein (Hoffman & Dukas, 1972, p. 24) are all said to have been interested in Plato's, Aristotle's, or Kant's philosophies since their childhood. Fundamental problems or philosophy are difficult and complex subjects and, therefore, can often be inconclusive. Since schools don't often deal with topics that don't have clear conclusions like these, teachers, parents and students all need to pay more attention to this aspect to encourage scientific creativity.

It is also found that '*taking notes*' needs to be encouraged to promote students' scientific creativity. Regarding this, Newton was so busy writing down many of his thoughts that it was difficult to find elegant handwriting in his notes (Christianson, 1996, p. 23), and it is well-known that Faraday made good notes about the lectures he heard (Russell, 1999, Location No. 235). The reason why '*taking notes*' is important is because creative students are apt to have many and various different ideas, and notes can help maintain and sustain them for a longer period of time. In this approach, initial notes are modified and developed over time, depending on additional experience and knowledge. In fact, even scientific knowledge was initially invented or proposed in an incomplete state and was then developed in an evolutionary manner. For example, Lakatos (1994) described how the atomic model evolved from Bohr's initial simple and incomplete model to the more detailed and articulated model we know now.

For the two statements related to the aesthetic aspects (statements VII.1 and VII.2, interest and talent in music or poetry), the mean value of the importance awareness was very low at 0.13 compared to the total average value of 1.84. Of course, creativity is area- or content-dependent. That is, creativity in science has different features from creativity in other fields or areas (Baer, 1991; Conti et al., 1996). However, there is something in common between science and art in terms of creativity. In other words, just as it is important to express our own new feelings or ideas differently in music or poetry, new scientific findings also need to be expressed through new languages, explanations, or models (Shin & Park, 2020). In schools, many students think that scientific knowledge they are taught is the truth, but the nature of science emphasizes the 'tentativeness of scientific knowledge' (Akerson et al., 2006; Lederman et al., 2002). That is, scientific knowledge is subject to change. Therefore, in order to encourage scientific creativity, science teachers, parents and students need to pay attention to how students express their own ideas with their own language when suggesting new hypotheses to explain a phenomenon, drawing a new conclusion about their scientific inquiry and so on.

According to the results, half of the 30 statements showed differences in the perception between the student group and the parent and/or teacher groups. In this case, attention needs to be paid to these differences because these differences may cause conflict between what students want and what they are encouraged to do. The main feature of this difference is that while students mainly place more importance on active aspects (i.e., *making and experiment*), teachers and/or parents mainly emphasized learning or thinking aspects (i.e., *giving effort for a long time and thinking deeply to solve problems with curiosity, summarizing and visualizing what they grasp the point in the learning by themselves*).

In fact, these two aspects (*activity vs thinking/learning*) are complementary elements in the behavioral characteristics of scientific creativity. Therefore, if a student follows the guidance of the parent/teacher well and the teachers/parents pay attention to the student's attention, then these differences in perceptions are not important. However, if teachers and parents only emphasize what they think is important, they may create an imbalance while trying to encourage scientific creativity.

According to previous research (Shin & Park, 2020) that examined the behavioral characteristics of creative physicists based on the literature that described various episodes during their growth period, about one-fourth of 210 episodes extracted from the literature analysis belonged to Category I (making) and II (inquiry/experiment). This means that the activity aspect cannot be ignored and is an important part of scientific creativity. In fact, it is not difficult to see that Newton, Maxwell, Einstein, and Feynman, well known as theoretical physicists, loved making and experimenting a lot as children and showed talent for it. For example, Maxwell "loved apparatus and had considerable manual dexterity" (Segre, 2012, Location No. 2857), Newton was also interested in special inventions and machines (Christianson, 1996, p. 13), and Feynman is famous for making various devices as a child (Feynman & Leighton, 1985, pp. 20-23). Therefore, teachers and parents need to understand the importance of the activity aspects for scientific creativity and to encourage students' behaviors related to it.

Finally, it is necessary to pay attention to the difference in perception between teachers and parents because the two groups can give different guidance to the students, and as a result, students can also experience conflict. Regarding this, parents thought learning aspects (*summarizing what students learn by themselves and read many*



books) were more important while teachers perceived thinking aspects (*deep thinking with curiosity*) to be more important. It is anticipated that parents may have greater interest in aspects related to studying. Moreover, some parents may like curiosity and deep thinking less because curious students may seem distracted by a wide range of interests or often miss what they have to do by falling into deep contemplation.

However, Newton was distracted by seeing the sun light passing through the garden in front of his house (Christianson, 1996, p. 14), and Maxwell was obsessed with observing beetles rather than playing with other boys at school (Forbes & Mahon, 2014, p. 132). Einstein is also said to have liked daydreaming and meditation (Issacson, 2007, p. 11). Therefore, parents need to adopt an attitude of watching and waiting when students display curiosity and deep thinking even when these behaviors do not quickly show clear results.

Conclusions and Implications

Based on the assumption that teachers' or parents' perceptions of scientific creativity play an important role in creating a learning environment that affects students' scientific creativity, the perceptions of teachers, parents, and students of behavioral characteristics related to scientific creativity were analyzed. For this, a list of behavioral characteristics regarding creative physicists during their growth period was used.

The results show that behavioral characteristics, such as *making something new using unprepared materials from nearby, taking notes and showing interest in fundamental problems, developing their own standards, and having concern for aesthetics*, are perceived as less important for all three groups. Nevertheless, it was discussed why such characteristics are important for scientific creativity and why they should also be emphasized. When comparing the perceptions of the three groups, an especially interesting finding is that the parent group provided greater importance to aspects related to learning, teachers to aspects related to thinking, and students to aspects related to activities such as making and experimenting. These differences in how the groups look at these three aspects are not problematic if they are encouraged in a complementarily fashion. However, if each group emphasizes different aspects as being important, then it can cause conflicts for the students.

Based on the results of this research, future research can be meaningful. First, research is needed to develop guidance materials of the behavioral characteristics that need to be encouraged for students' scientific creativity. In particular, it is necessary to encourage behavioral characteristics that all three groups perceive to be less important. For this, real-life episodes or instances of behaviors that actual scientists have shown during their growth period will be helpful. In addition, since some behaviors can be seen as abnormal behaviors in a negative way, such as excessive meditation, logically arguing, trying to make their own rules, and asking too many questions, guidance is also be needed to explain why these behaviors may appear in young creative physicists.

Second, this research assumes that the perception of creative behaviors by parents or teachers serves as an important factor to create learning environments that affect how students' scientific creativity is encouraged. To check this assumption, further research is necessary to check whether there is a change in students' scientific creativity when there are differences between students' perceptions and teachers' and parents' perceptions. That is, it will be possible to examine whether students become more creative in science in the future when there are fewer differences in the perceptions of students, teachers and parents, or what happens when creative behavioral characteristics are emphasized in a balanced manner. This kind of research requires significant hard work and observations over long periods of time, but this effort would be very meaningful.

Finally, it is necessary to point out limitations in this research. This research used a list of creative behaviors of physicists during their growth period. However, when examining the perceptions of the participants, the behavioral characteristics provided were simply introduced as behavioral characteristics of the scientists. Therefore, a list of behavioral characteristics of 'scientists' that includes areas other than physics should be developed to obtain more accurate comparisons of the perceptions of the participants. In addition to questionnaires, in-depth interviews will also be helpful to examine the perceptions more accurately.

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