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Abstract. *Teaching creativity is one of the major goals of science class. This study examined how much time is necessary to conduct a scientific creativity task requiring fluency in middle schools. To accomplish this, 76 and 45 scientifically gifted and ordinary students respectively generated as many ideas as possible for the creativity task. The results revealed that ordinary students spent, on average, approximately 20 minutes to generate 3.49 ideas per student. However, gifted students concentrated on the task for a longer time (roughly 60 minutes), and consequently generated greater (11.53) and more elaborate ideas. In comparing the ordinary students' fluency with their school science scores, no relationship was found between them. This indicates that only teaching science cannot guarantee the development of creativity. Therefore, it is concluded that teaching fluency in middle schools is necessary and can possibly encourage creativity, provided that teachers can secure a minimal amount of time required to do so. Finally, the limitations of this study and further studies are discussed.*

Key words: *fluency, gifted education, scientific creativity, teaching creativity.*

Daehyeok Kang

Yeongju Girl's Middle School, Yeongju, Korea

Jongwon Park

Chonnam National University, Gwangju,

Korea

Hanghwa Hong

Gwangju Science Academy for the Gifted,

Gwangju, Korea

CHANGES IN THE NUMBER OF IDEAS DEPENDING ON TIME WHEN CONDUCTING SCIENTIFIC CREATIVITY ACTIVITIES

**Daehyeok Kang,
Jongwon Park,
Hanghwa Hong**

Introduction

The call to develop creative thinking skills can be found in many countries. For instance, the American Association for the Advancement of Science [AAAS] maintains that "science classroom [s] ought to be a place where creativity and invention... are recognized and encouraged" (AAAS, 1990, p. 204). Korea's national science curriculum also includes a standard that entails individuals displaying creativity based on novel ideas, challenges, and fundamental abilities (MEST, 2011).

Scientific creativity consists of scientific knowledge and inquiry skills, as well as creative thinking skills (Park, 2004). Moreover, scientific thinking skills consist of various components, such as divergent, original, and associational thinking. Fluency, which has been regarded as an important factor in defining divergent thinking (Runco & Acar, 2012), can be defined as the number of distinct ideas (Runco, 1986) or ability to name as many objects as possible in a given time (Guilford, 1950).

Fluency is also a main factor in assessing scientific creativity (Hu & Adey, 2002; Mohamed, 2006; Sak & Ayas, 2013). This is because a person who can create greater numbers of ideas concurrently when compared to others may have additional opportunities to address important and original ideas (Guilford, 1950). For example, it is known that scientists who author many papers often publish more significant works (Over, 1989; Simonton, 1997; 2004). Therefore, developing fluency is a prerequisite condition for generating creative products.

Therefore, in order to teach creativity in a more effective way, greater understanding is needed concerning the features of fluency. First, it should be understood how much time is required to encourage fluency during activities. Although some argue that a creative work can occur in a relatively short time frame, others assert that creative ideas emerge after a significant period of time is dedicated to a task (Madjar & Shalley, 2008). For instance, Orlet (2008) emphasizes that scientists generally make new discoveries following an incubation period. In this case, the incubation for creative works requires extra time before activation can occur.



However, allotting additional time for creative activities during ordinary science lessons can be difficult, since classes are often scheduled to master a given scientific concept as defined by the science curriculum. Indeed, nearly 75% of both Korean and American in-service teachers agree that there is a lack of sufficient time for creative activities because of pre-determined required content and test preparation (Hong & Kang, 2010).

To resolve this problem, Park (2012) suggests mini creativity activities requiring just 10-15 minutes which are feasible during regular science lessons. However, no conclusive data exists concerning the number of ideas that students can produce during this time period. Therefore, this study investigated the time required for conducting a creativity task demanding fluency.

Second, gifted students have been used to represent students showing high intellectual or academic ability (Manning, 2006). Therefore, a high level of knowledge has been generally used to distinguish gifted students from others. However, it also has been emphasized that creativity is a feature of gifted students (Kaufman, Plucker, & Russell, 2012; Renzulli, 2011; Torrance, 1984). Therefore, it could be assumed that the fluency of gifted students exceeds their ordinary peers since fluency is one of the primary features of creativity. To check out this assumption, this study investigated the difference in fluency between gifted students and ordinary students.

Third, many have concerns on the interrelationships between fluency and intellectual ability, especially regarding school achievement (Jauk, Bebedek, Dunst, & Neubauer, 2013). Some studies (e.g., Asha, 1980; Bolandifa & Noordin, 2013; Kaboodi & Jiar, 2012; Powers & Kaufman, 2004) argued that interrelationships exist between fluency and school achievement, while others assert that there is either no relationship (e.g., Olatoye, Akintunde, & Yakasi, 2010; Palaniappan, 2007) or very little relationship (e.g., Sen & Hagtvet, 1993). If an interrelationship does indeed exist between fluency and school achievement, then it can be deduced that improvement of fluency can be expected from the development of academic ability or vice versa. In contrast, if there is no relationship between these factors, teaching science contents alone cannot guarantee the improvement of fluency. Then, we would need to give extra efforts to teach fluency in schools. Therefore, this study investigated the correlation between students' school achievement and fluency.

Research Questions

Based on the background above, this study investigates the following three questions:

1. 1. How does the number of ideas (as an indicator of the fluency) change in relation with time when conducting a creative activity?
2. 2. Do changes in fluency differ between gifted and ordinary students, according to time?
3. 3. Is there a correlation between students' academic achievement and fluency?

Theoretical Background

Fluency

Feldhusen and Goh (1995) maintain that fluency should be included in assessing creativity along with other factors, such as creative products. Many studies have demonstrated a close relationship between fluency and creativity. For example, Batey, Furnham, and Safiullina (2010) reported a high correlation ($r = .78$) between fluency and comprehensive creativity scores. Runco and Acar (2012) noted that fluency could be a sufficient measure of divergent thinking, and thus indicate one's potential for creative thinking. Mouchiroud and Lubart (2001) focused on the relationship between fluency and originality, and found that correlations between them were occasionally more than .60. Moreover, Diakidoy and Constantinou (2001) found a strong correlation between originality and the number of ill-defined responses to physics problems among college students ($r = .71$), while Runco (1986) discovered low discriminant validity between fluency, flexibility, and originality among ninety-seven gifted students.

Therefore, a claim can be made that creativity can be estimated based on fluency. In fact, Over (1989) analysed psychologists' research based on a citation index and found that, although the frequency of their publications decreased with age, the ratio between their overall work and publications that were cited did not change as a value of 0.5. This means that the number of papers published by psychologists could be indicative of the quality of their work.

One explanation for strong correlations between fluency and creativity could be that fluency is a prerequisite for creativity. For instance, Thomas Edison made 1800 attempts before successfully developing the light



bulb (cited in Shaw, O'Loughlin, & McFadzean, 2005, p. 396), thus indicating that many attempts are required to invent new things. Furthermore, it is known that after Albert Einstein declared the completion of his unified field theory he subsequently recanted it three times upon finding errors (Root-Bernstein, 1999). This means that many trials should be performed before deeming an idea or project completed. In relation to the two aforementioned stories it is worth mentioning that Einstein, Darwin, and Poincare published 248, 119, and 500 papers respectively. Moreover, Edison filed 1093 patents while most Nobel winners wrote 3.9 papers on average each year (Simonton, 1997; Runco, 2007).

Creativity and Academic Achievement

Asha (1980) found a strong correlation between creativity and the academic achievement of 800 middle school students with an average age of 14; Bolandifa and Noordin (2013) reported the same result among 100 college students ($r=.81$). In contrast, other studies reported meaningful, albeit low correlations between creativity and academic performance. For example, Powers and Kaufman (2004) found a low relationship between creativity and graduate students' GRE scores and fluency ($r=.24$). Similarly, Sen and Hagtvet (1993) reported a minor correlation ($r=.17$) between creativity and academic achievement among 300 eleventh grade students. Kaboodi and Jiar (2012) reviewed ten published papers and found that the average correlation between creativity and academic achievement was $r = .32$.

In parallel, there are studies suggesting that no relationship exists between academic performance and creativity. For instance, Palaniappan (2007) found no correlations between academic achievement and creativity among 467 middle school students with an average age of 13. Furthermore, Olatoye et al. (2010) reported no relationship between academic achievement and creativity among 235 college students. Likewise, Lee (2006) did not find any relationship between academic performance and creativity among Korean sixth grade students.

Other studies failed to find a consistent relationship between school performance and creativity. For example, Balgiu and Adir (2014) noted that while no overall relationship could be observed between school achievement and creativity among 86 college freshmen, partial relationships did exist between them from $r=.25$ to $r=.29$. Additionally, Chamorro-Premuzic (2006) conducted a study composed of 307 college students and found a positive relationship with creativity in the oral test, project task, and comprehensive examination ($r = .13$ to $r = .45$), and a negative relationship with creativity in the multiple-choice and open-ended test ($r = -.30$ to $r = -.58$).

As the above literature review demonstrates, a consistent relationship between school performance and creativity cannot be established, possibly due to differences in student and teacher features and/or learning environments. Differences in the creativity and achievement tests among schools could also explain these inconsistent findings. In other words, it is difficult to observe any relationship between academic achievement and creativity if a school assessment requires students to choose a correct answer using only convergent thinking skills (Runco, 2004, p. 670). In such situations, because we cannot expect students' creativity based on school achievement, extra effort should be exerted to develop student creativity in schools.

Methodology of Research

For the first research question of this study, two creativity activity tasks requiring fluency were developed at first (Figure 1 & 2). These tasks were applied to gifted students and ordinary students, and the number of students' ideas was counted per minute. Then, the differences in the number of ideas and the time required to conduct the task between two student groups were analysed for the second research question. Finally, for the third research question, we analysed the correlation between their fluency, that is the number of ideas generated in the activities, and science test score in their school.

Scientific Creativity Tasks

Two creativity science activity tasks from a series developed by Park and Kim (2013) were used in this study (see Figure 1 & 2).



Taking measurements using other methods

Task: When a scientist measures weight, a piezoelectric material capable of generating electricity can be used instead of a spring scale.
When measuring length, a meter stick is generally used. Suggest other tools or methods to measure length or distance. ... Suggest as many different ideas as possible...



Figure 1: Task 1 focused on developing fluency.

Scientific solutions to issues in everyday life: Waste

Task: There are many scientific solutions to issues related to everyday life.
There are many appliances in our homes that are no longer used and merely occupy space. How might these appliances be recycled? ... Present as many different ideas as possible. ...



Figure 2: Task 2 focused on developing fluency.

Participants

In Korea, there are various types of gifted centres in science and mathematics. The Center at Chonnam National University in Korea also selects gifted students from elementary and middle schools and teaches them for about 100 hours a year. After finishing the first year course, some of them, through the selection process, can continue the learning in the third year course. Forty five gifted students participated in this study were randomly selected from this centre.

Seventy-six ordinary students were randomly selected from two classes in the general middle school located in a metropolitan city in Korea. Their cognitive ability was spread from low ability to high ability likely as is ordinary schools. Table 1 presents demographic information related to the students who participated in Tasks 1 and 2.

Table 1. Participants' demographic information.

Participants	Task 1		Task 2	
	Ordinary	Gifted	Ordinary	Gifted
Grade	Nine	Eight	Nine	Eight
No. of Students	39	22	37	23
Subtotal	61		60	
Total	121			

Data Collection

The worksheet, including the task, was given to students and then they were asked to write their ideas on the worksheet. There was no time limit to complete the task. While completing the task, the researcher informed students as each minute passed, and reminded them to mark every minute on their worksheet. Figure 3 partially shows how participants marked their worksheets while completing Task 2.



- 냉장고의 문에서 문을 떼어내고 1분 그안의 받침대나 선반을 모두 제거하면 성인남성도 들어갈 정도의 크기가 남으므로 2분 그 문틈을 침대나 욕조 혹은 뒷밭이 위로 오게 높여서 소파를 만들수 있을 것 3분 같다.
- 사람의 프린터를 각각의 집에 여러개씩 달아 풍력 4분 발전기를 만들수 있을 것 같다.
- 오븐의 문을 떼어내고 오븐의 가운데 선반을 5분 설치하면 책꽂이로 사용할 수 있다. 6분.
- 전자레인지의 뒷면을 아래로 오도록 하고 문을 떼어내면 그 문 안의 공간에 큰 식물을 심을 수 있는 화분이 된다.

Figure 3: A student's worksheet containing time markers for seven minutes. The first paragraph reads, "After detaching the refrigerator door [first minute], remove the shelves and drawers from the refrigerator's main body. Next, a large space can be made for an adult [second minute] to use as a bed, bath tub, ...!"

Data Analysis

The ideas presented by the participants were tallied. Some ideas were not included in the analysis for several reasons. In one case, the reasoning was not sufficiently scientific (e.g., for Task 2 one respondent suggested lighting up a room by putting fluorescent lamps into an oven). In another case, the response was unintelligible (e.g., for Task 1 a respondent suggested a method for measuring length by spraying water with a hose). Another participant restated similar ideas for Task 1, which involved measuring with pencils, with photos, and with printer papers. Finally, one participant failed to provide a complete response: they began by suggesting a method for measurement wherein people lay down and are then counted, but did not develop the idea further.

Graphs indicating changes in the number of ideas according to time were drawn, and an equation for a trend line was written. Comparisons between the ordinary students and gifted students were performed and analysed statistically using t-tests. For ordinary students, the relationships between the number of ideas generated in the task and their science scores in their school were statistically analyzed and presented in a scattered plot graph. Science scores were based on a middle school achievement test. SPSS 21 was used for statistical analysis.

Results of Research

The number of Ideas Generated by General Ability Students Based on Time

The time interval used to count the number of ideas suggested on the worksheet was fixed at two minutes since the number of ideas for a one minute interval was too small. Table 2 shows the number of ideas generated by ordinary students every two minutes, while the accumulated number of ideas is displayed in Figure 4.



Table 2. A number of ideas generated by the ordinary students.

Time (Minutes)	Task 1 (n=39)		Task 2 (n=37)		Accumulated average no. of ideas (Per person)
	Accumulated no. of ideas	Average (Per person)	Accumulated no. of ideas	Average (Per person)	
2	50	1.28	41	1.11	1.20
4	72	1.85	59	1.59	1.72
6	87	2.23	79	2.14	2.18
8	93	2.38	92	2.49	2.44
10	102	2.62	104	2.81	2.71
12	110	2.82	117	3.16	2.99
14	117	3.00	128	3.46	3.23
16	124	3.18	137	3.70	3.44
18	126	3.23	139	3.76	3.49
20	126	3.23	139	3.76	3.49

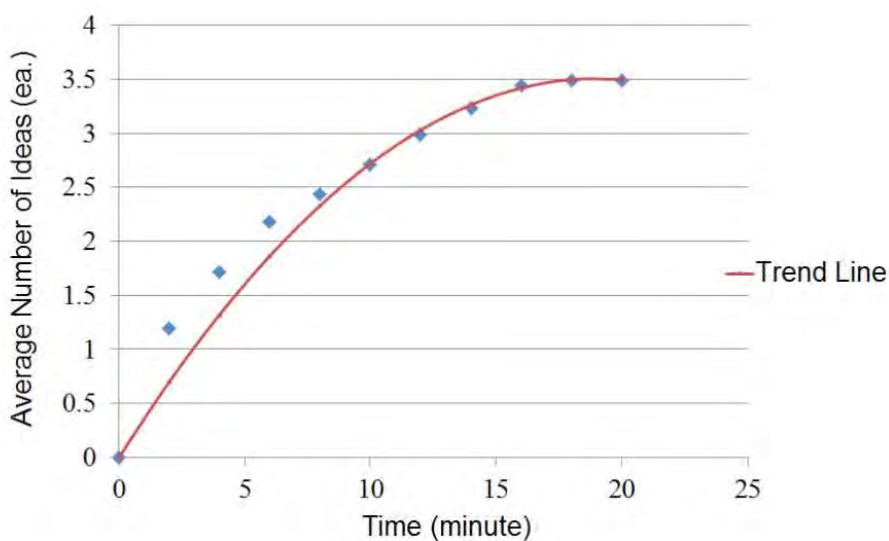


Figure 4: Accumulated average number of ideas generated by the ordinary students based on time.

An examination of Table 2 reveals that on average the ordinary students generated 3.49 ideas per person during a 20 minute period. The equation for the trend line is $y = -0.0097x^2 + 0.369xy = -0.0097x^2 + 0.369x$ and $R^2 = 0.909, R^2 = 0.909$, where yy and xx indicate the accumulated number of ideas and time respectively (see Figure 4). Based on this, it can be inferred that students cease to generate ideas after approximately 19 minutes (in the equation, $-0.0097 \times 2x + 0.369 = 0 - 0.0097 \times 2x + 0.369 = 0$, x value when the tangent line's slope is zero). Moreover, to generate 3.14 ($= 3.49 \times 0.9$) ideas (which accounts for 90% of all ideas), students require roughly 13 minutes (x value when $y = 3.14y = 3.14$).

Based on these results, about 15 minutes is required to complete a task designed to encourage fluency. Thus, teaching fluency is possible in an ordinary school context provided that teachers secure a minimal amount of extra time in their teaching plans.

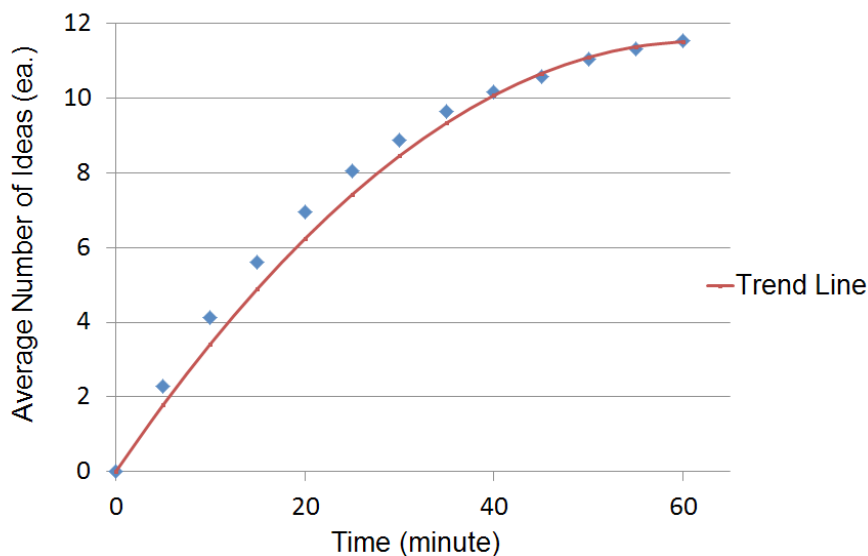


Differences in the Number of Ideas Generated by Gifted Students Based on Time

Gifted students generated more ideas when compared to their ordinary counterparts. Consequently, their ideas were counted in five rather than two minute intervals. Table 3 displays the number of ideas generated by gifted students every five minutes, while the accumulated number of ideas is shown in Figure 5.

Table 3. A number of ideas generated by the gifted students.

Time (Minutes)	Task 1 (n=22)		Task 2 (n=23)		Accumulated average no. of ideas (Per person)
	Accumulated no. of ideas	Average (Per person)	Accumulated no. of ideas	Average (Per person)	
5	52	2.36	51	2.22	2.29
10	97	4.41	89	3.87	4.14
15	129	5.86	123	5.35	5.61
20	162	7.36	151	6.57	6.96
25	189	8.59	173	7.52	8.06
30	212	9.64	187	8.13	8.88
35	229	10.41	204	8.87	9.64
40	242	11.00	215	9.35	10.17
45	253	11.50	222	9.65	10.58
50	262	11.91	234	10.17	11.04
55	270	12.27	239	10.39	11.33
60	274	12.45	244	10.61	11.53

**Figure 5: Accumulated average number of ideas generated by the gifted students based on time.**

An examination of Table 3 reveals that on average the gifted students generated 11.53 ideas per person during a 60 minute period. The equation for the trend line is $y = -0.003x^2 + 0.372x$, where y and x indicate the accumulated number of ideas and time, respectively (see Figure 5). Based on this, it can be inferred that students cease to generate ideas after approximately 62 minutes (in the equation, $-0.003 \times 2x + 0.372 = 0$, x value when the tangent line's slope is zero). Furthermore, to generate 10.08 ($= 11.53 \times 0.9$) ideas (which account for 90% of all ideas), students require about 42 minutes (x value when $y = 10.08$).

Based on the above results, gifted students generated ideas for a longer period of time (62 minutes) when compared to their ordinary counterparts (19 minutes); also, the gifted students exhibited higher levels of task commitment. Furthermore, because the gifted students generated more ideas on average than their counterparts (11.53 versus 3.49, respectively), their fluency was superior. As mentioned earlier, fluency is an indicator of creativity, and we can conclude that the gifted students exhibited greater creativity than the general ability group; consequently, fluency can be used to distinguish between the gifted and ordinary groups.

Comparison between the Ordinary and Gifted Students

To compare the number of ideas generated by both groups, the time interval for the general ability group was changed to five minutes, which is the same interval used with the gifted students. Table 4 shows that, when compared to their ordinary counterparts, the gifted students generated more ideas within the same time frame.

Table 4. An average number of ideas generated by both groups every five-minutes.

Time (Minutes)	An average number of ideas generated per student every five minutes		
	A: Gifted students (n=45)	B: Ordinary students (n=76)	Difference (A-B)
5	2.29	2.00	0.29
10	1.85	0.72	1.13
15	1.47	0.65	0.82
20	1.36	0.13	1.23
25	1.09	0	1.09

For the first five minutes the difference between both groups is statistically insignificant ($t = 1.587$, $p > .05$). Therefore, the number of words for every generated idea was checked, since the number of words comprising each one could correspond with the concreteness or elaboration of an idea. Table 5 shows that, on average, the gifted students used significantly more words for each idea than their counterparts ($t = -3.982$, $p < 0.01$). By comparing the actual substance of the ideas generated by each group (see Figure 6), it was clear that the gifted students' responses were more elaborate and concrete.

Table 5. The number of words comprising each idea generated by both groups for the first five minutes.

Group	N	Average number of words	t	p
Ordinary	76	22.3	-3.982	0.000
Gifted	45	34.4		



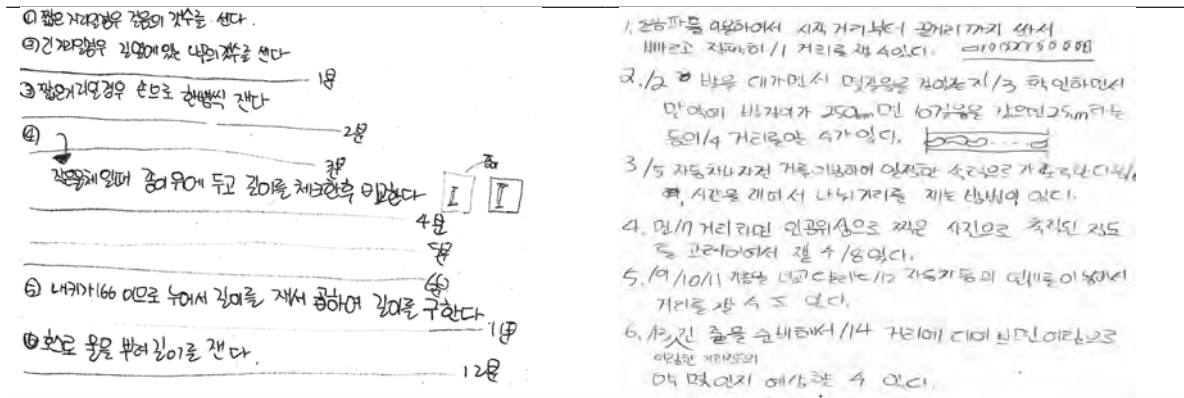


Figure 6: Sample ideas generated by an ordinary and gifted student on the left and right respectively. The first idea on the left reads, "For a short distance, count the number of steps"; on the right, in the second idea, the student wrote, "At first, count the number of steps by contacting each foot. If the length of the [subject's] foot is 250 cm, and he walks 10 steps, we know that the distance is 25 m."

The Relationship between Fluency and Science Scores among Ordinary Students

In Table 6, fluency is determined by the number of ideas generated by the ordinary students. Both Table 6 and Figure 7 show that no relationship exists between fluency and science scores among ordinary students.

Table 6. Correlation between fluency and science scores among ordinary students (n=76).

	Fluency
Science scores	-0.070
<i>p</i> =0.546	

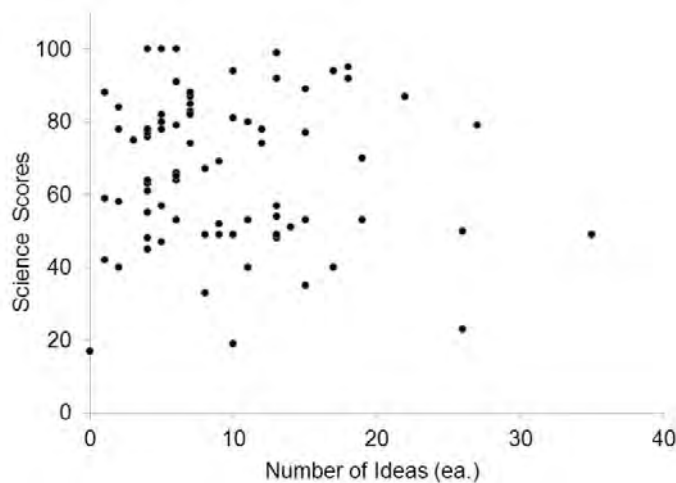


Figure 7: Distribution of the number of ideas according to general students' science scores.

As mentioned earlier, no correlation between them could be caused by examinations and/or teaching methods that fail to effectively evoke or encourage creative thinking, or because academic cognitive abilities are unrelated to creativity. Therefore, the results of this study suggest that teaching fluency should be encouraged since teaching science alone does not guarantee improved fluency or creativity.



Discussion

Regarding the first research question, it was found that 19 minutes were required for an ordinary student to generate 3.5 ideas and 13 minutes to generate 90% of all ideas. From this result, we confirmed that teaching creativity can be achieved in an ordinary science curriculum if a minimal commitment of time can be made. Of course, this kind of short activities cannot guarantee the development of scientific creativity. To do this, iterative learning experiences are recommended for many years from elementary school to high school (Park, 2012). This assertion is based on the assumption that scientific creativity is a form of a thinking style or a habit rather than a cognitive ability (Park, 2011). That is, even if the scale of an activity is small, if students experience such creativity activities repeatedly for many years, we can expect improvement in creativity. However, as this suggestion has not yet been tested in schools yet, actual application of it is necessary in the next study.

Secondly, compared to ordinary students, gifted students generated a number of ideas for a longer period of time: on average, a gifted student used 62 minutes for generating 11.5 ideas, and 42 minutes for generating the 90% of all ideas. This means that gifted students were more fluent and showed a higher level of commitment to the task on hand. It was also found that their ideas were more elaborate and concrete, indicated by a number of words used in each idea. As a result, we concluded that gifted students were more creative because of their fluency, task commitment, and elaboration, which are typical components in the definition of creativity. Furthermore, it can be inferred that fluency, task commitment, and elaboration can be used as standards for identifying the gifted from the ordinary students.

However, the gifted students participated in this study were middle school students selected from ordinary schools, who have participated in special programs developed by our university in the area of science and mathematics. Therefore, it is also possible that their creative attributes, such as fluency, task commitment, and elaboration, may have been nourished and developed through the participation in the special programs. In fact, many studies have reported that creativity can be developed with appropriate programs for improving creativity (e.g., Scott, Leritz, & Mumford, 2004; Park & Jee, 2010). Therefore, another study will be necessary to test whether their creative attributes were developed through the special programs provided by our university or not.

Finally, in the literature review on the relationship between creativity and academic achievement in school, we discussed that the studies investigating the relationship between them have not resulted in consistency; some studies reported a strong relationship while others showed weak relationships. Moreover, some studies failed in finding a statistically significant correlation between them. In this study, we did not find any correlation. As a result, it can be concluded that extra efforts for teaching creativity in ordinary schools are necessary, because teaching science contents focusing on academic aspects does not guarantee the development of creativity. In fact, an ordinary science curriculum also has stressed the development of creativity in many countries (e.g., AAAS, 1990; MEST, 2011). However, teaching creativity in ordinary science classes is not common. For example, Yager (1989) pointed that convergent thinking, rather than divergent thinking or more creative processes, was emphasized in school science curriculums, and Cropley (1992, p. 20) also criticized that nearly 95% of teachers considered memorization, accuracy, or recognition of learning materials as important aspects of learning science. Even though these comments are old, there may be a little difference in the situation of current science classes. Therefore, we need to emphasize a special teaching effort for improving creativity in the science classroom, if the development of scientific creativity is one of the major goals of science learning.

Conclusions

Fluency is an important component of creativity, and it should be taught in schools in order to foster creativity. This study demonstrated that there is no relationship between fluency and school science scores. Hence, teaching science alone cannot guarantee the development of scientific creativity, and attempts should be made to teach fluency in ordinary schools.

However, allocating extra time to teach fluency is not easy, since teachers must also adhere to a stringent and predefined science curriculum. If the amount of time necessary to conduct fluency exercises can be decreased, teachers may find it possible to integrate these activities into their lessons. In fact, this study shows that only about 15 minutes is required to conduct a fluency activity under ordinary school conditions. Of course, a single 15 minute activity cannot ensure the development of creativity. However, teachers can coordinate such tasks on a weekly basis, affording them an opportunity to conduct creativity activities roughly 30 times a year. If students



consistently experience these types of activities from elementary school through senior high school, it should contribute to enhanced creativity.

This study was limited by the inclusion of only two small tasks, which were used to measure fluency. Also, the number of ideas generated by participants was examined, but not their quality. While the introductory section noted that a large number of ideas are often a prerequisite condition for "good" ideas, it is nevertheless necessary to examine the quality of ideas for more authentic creativity. Likewise, more data should be obtained regarding other components that embody creativity, such as originality, flexibility, unconventional thinking, and associational thinking.

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Daehyeok Kang

M.S., Science Teacher, Yeongju Girl's Middle School, 750-902 Yeongju, Korea.
E-mail: saylovei@daum.net

Jongwon Park
(Corresponding author)

Ph.D., Professor, Chonnam National University, 500-757 Gwangju, Korea.
E-mail: jwpark94@jnu.ac.kr

Hanghwa Hong

Ph.D., Science Teacher, Gwangju Science Academy for the Gifted, 500-480 Gwangju, Korea.
E-mail: hthree@hanmail.net

