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Effects of STEAM Lessons Using Scratch Programming Regarding Small Organisms in Elementary Science-Gifted Education

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스크래치 프로그래밍을 활용한 '작은 생물' STEAM 수업이 초등과학 영재에게 미치는 효과

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국문초록

본 연구의 목적은 스크래치 프로그래밍을 활용한 초등과학 '작은 생물' STEAM 수업을 개발하고 적용하여, 초등 영재학생의 창의적 인성, 창의적 문제해결력, 과학적 태도의 향상에 어떠한 영향을 미치는지 알아보고자 하였다. 개발한 STEAM 수업은 과학 지식과 스크래치 프로그래밍을 통합한 내용적 융합의 방법을 통해 학습자가 창의적 설계와 감성적 체험을 효과적으로 경험할 수 있도록 설계되었다. 연구 대상은 26명의 초등과학 영재학생들이었으며, 양적 및 질적 접근을 통해 자료를 수집하였다. 7차시의 수업을 적용한 결과, 개발한 STEAM 수업이 창의적 인성 및 과학적 태도에 효과가 있었다. 창의적 인성 하위 요소 중, 독립성에서 효과가 있었으며, 과학적 태도 측면에서는 자발성 및 인내심에서 유의한 상승을 보였다. 본 연구는 생명 과학 및 컴퓨터 프로그래밍처럼 STEAM 수업을 위한 효과적인 수단을 통합하는 일이 과학 기술에 대한 학생들의 창의성과 흥미를 신장시킬 수 있음을 제안한다.

주요어 : STEAM, 스크래치, 작은 생물, 창의적 인성, 창의적 문제해결력, 과학적 태도

I. Introduction

Society is changeable and fluid, and technology is particularly becoming advanced from day to day. Advanced technology means having capabilities of leading an abundance of civilization. Scientific and technological advancement could directly contribute to a competitive capacity at the national level, so it's an important task for the nation to educate individuals as human resources of future science and technology (Zollman, 2011). Creativity is an important factor for surviving in the knowledge-based society. The increasing demand for creativity, such as problem solving ability and other aspects directly related to creativity, encourage students to develop innovative ideas. As economic emphasis is based on knowledge, creation of techniques and information through organization of new knowledge beyond the acquisition of simple knowledge requires individuals to have creativity and proficiency in the fields of science and technology, which are necessary in our society (Cho *et al*., 2011).

STEAM literacy incorporating various fields of knowledge and solving complex problems is required these days, and this tendency can appear in the form of the STEAM education. According to social needs, it has been proposed that educational approaches of STEM/

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STEAM lessons through integration of science, technology, and engineering is like Engineering by Design (EbD) or The Engineering is Elementary (EiE) (Conningham, 2009; NCTL, 2009; ITEEA, 2011).

Research into STEAM education, including the development and application of lessons, is very well established (Brown, 2012; Kwon & Ahn, 2012). However, children's STEAM programs about organisms based on integration between science and computer are still insufficient. Some of the valuable published works of instructional approaches integrated two different disciplines of science and computer education- for example, the works of Lee *et al*. (2013), Lim (2012), Shin and Park (2011). Most of these studies have begun from the viewpoints of computer educators, whereas specific knowledge on science pedagogical content is often incomplete, in comparison to plentiful computing skills in their programs. In addition, there are opposite effects of application computers in class; for instance, attitude of scientism which students consider to get easily whatever they intended due to web (Lim & Jeong, 2004).

Despite splits in the success or failure between application computer programming and science education, a few studies have indicated that programming could be an expedient in learning science for children (Lee *et al*., 2013; Lim, 2012). There is a recent work in this field; for example, using Scratch has a positive effect on students' learning achievement, which is suitable for subject matter education. Lim (2012) studied the application of Scratch programming to science class, based on the unit of 'The seasonal change' in elementary science. In this study, we conducted with the aims to provide a practical example of STEAM lessons, by using Scratch programming regarding specific theme connected to curriculums in school.

Scratch, which is one of programming tools, is useful because it is easy to learn and intuitively acquire its way of use, which raises learners' interest (Cho *et al*., 2008). For example, Scratch can be widely used due to its advantages of being appropriate to improve abilities by using various kinds of media that are applicable for any age group (Romero, 2010). In Korea, it has also been shown that through the education programs using Scratch, the learners are highly motivated (Song *et al*., 2008; Yang, 2010), and it affected on the process of positive learning (Lee & Lee, 2008; Yoon *et al*., 2009) as well as problem solving abilities (Song *et al*., 2008; Ryu & Lee, 2012).

The contents regarding 'Small Organisms' in elementary science are important not only for its influence on everyday life, but also in making young students to understand the diversity and commonness of life. However, teaching and learning organisms in actual schools are limited by the difficulties in organisms collection, local contiguities, etc. (Choi *et al*., 2000). In spite of the importance of micro-organisms in their everyday lives, a large number of students' negative idea about micro-organisms prevalent, so the teachers should consider teaching about micro-organisms appearing in a range of contexts (Byrne, 2011). Scratch is more effective than the existing ICT education, and it could be an alternative to solve such limitation in teaching and learning.

The authors concentrated a couple of domains as a priority, because they have attracted attentions to the field of Korean education, especially STEAM. It seems that both the creativity and nature of science education in Korean curriculum of science education is being significantly considered. First of all, it's very difficult to reveal what a creative personality is. Yoo *et al*. (2011) tried to extract sub factors of people with creative personality, depending on existing tests and theories of creativity. They explained creative personality as inquiry, task commitment, aesthetic appreciation, intellectually openness, independent in making judgments, risk sensitivity, etc. Prescribed conceptions of creative personality for elementary students focused on task commitment, curiosity, aesthetic appreciation, intellectual openness, independence, and risk sensitivity.

The meaning of creativity can be new and proper solving methods during the process of problem solving, whereas problem solving means make a new solution for problems. For example, Isaksen and Treffinger (1985) explained it as an ability of problem solving with the use of creative and productive thinking, which is affected by convergent and divergent thinking, in the process of understanding problems, producing ideas, planning actions, and practicing. Dacey *et al*. (1998) suggested that factors of creative problem solving ability are affected by biological factors (neuron, hormone, regulatory gene, brain growth, interaction of hemisphere and cerebrum of gray matter), psychological factors (patience to indistinctness challenging spirit toward adventure, capability of self-control, metacognition, self-evaluation, self-efficiency, ability to delay pursuing pleasure, etc.), cognitive factors (knowledge and skill in general or specific fields, divergent thinking), micro sociological environments (family members, relatives, and living environment), macro sociological environments (school, neighborhood, workplace, religion, tribe, political · economical · social environments). Isaksen and Treffinger (2004) suggested many versions of creative problem solving, and especially the system that help design and develop meaningful output was addressed through CPS version 6.1™. The tools of the productive thinking make individuals and groups to recognize opportunities, meet the challenges, overcome concerns and manage about process.

To define creativity as a phenomenon to explain a new concept, a useful framework was suggested by Rhodes (1961). He proposed the 4 P model of creativity which is creative 'person', 'process', 'product' and 'press'. Everyone possesses the creativity, and can teach and learn for creative process. Urban (1995) felt a necessity of a complex viewpoint to include not only interdependence of 'person' and 'environment', but also an interaction between cognitive and characteristic factors in the process of creative activity. Thus, he suggested 4PE interactive model consisted of 'problem' to solve creatively, 'process' to create a product, 'product' revealing creativity, creative 'person' and 'environment' as an external condition necessary for creative expression.

Scientific attitudes can be explained with behaviors toward science to life, and thinking and taking scientifically around phenomena are included. Kim *et al*. (1998) defined that evaluation of affective domain related to science consisted of three main categories such as perception, interest and scientific attitudes, and the scientific attitudes among them were subdivided into 6 subcategories. The factors of scientific attitudes were curiosity, open-mindedness, critical-mindedness, cooperation, voluntariness, endurance, creativity. According to this theory, if a student thinks positively about the subject of science, his or her grades on the scientific attitudes test can reveal such factors with higher scores.

Studying the effects of STEAM lessons by using programming in science education will help to inform and support the appropriate STEAM program development to achieve creativities of young learners.

The primary research question is as follows: do the STEAM lessons using Scratch programming in regards to small organisms improve the abilities of elementary students who are gifted in science?

This article describes answers to the research questions through two subquestions as follows:

1. How can STEAM lessons be developed by fusing life science and Scratch programming?
2. How do STEAM lessons develop creative personality, creative ability in problem solving, and scientific thinking in elementary students who are gifted in science?

II. Methods

The STEAM lessons were developed to cultivate learners' creativity using scratch programming focused on small organisms, and they were executed to 26 gifted students to participate for 7 class hours. For one-group pretest-posttest design quantitative studying, their creative personality, creative problem solving ability, and scientific attitude were measured by the testing tool developed by Yoo *et al*. (2011), Jin and Son (2011), and Jang and Shin (2009). Group semi-structured interview was also performed with the intention of enriching the dataset, and the interviews were transcribed as supporting qualitative information. The specific methods for this study are shown in the sections below, and they mainly consist of development of the STEAM lessons, the participants, tests, and semi-structured interview.

1. Development of the STEAM Lessons

The STEAM lessons using Scratch programming was designed to enhance creativity and achievement for the scientifically gifted students who are in 6th grade, in STEAM fields. The STEAM lessons integrated computer programming in the learning of science concepts, as shown in Fig. 1.

The instruction design for STEAM lessons, using Scratch programming regarding 'Small organisms', was organized according to Lee *et al.*'s (2013) *Scientific Inquiry-based STEAM Education Model.* A-D-B-A model emphasized discovering knowledge, importance of the process of productions, close connection with real world, problem solving through experiments, and practical works. Furthermore, the process of developing lessons using Scratch (Shin & Park, 2012) was applied for developing the STEAM lessons of this study. The contents of STEAM lessons were selected from the 2007 revised national curriculum in Korea.

The developed lessons were reviewed by 10 science educators and 6 computer educators, composed of professors, PhD candidates, and teachers in graduate course and elementary school. They checked and discussed the contents and components of the STEAM program, according to criteria developed by Park *et al*. (2012), so their advices were used to modify the STEAM lessons. Moreover, index of content validity (CVI) was calculated by using a formula, with 5 point Likert scales ranging from unlikely (20 points) to very likely (100 points).

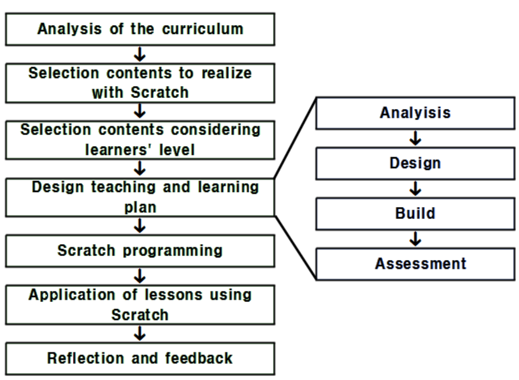

Fig. 1. Procedure of developing the STEAM lessons (Shin & Park, 2012)

2. The Participants

The STEAM lessons offered an opportunity to participate for 7 class hours to the 26 elementary 6th graders (12-years-old 21 boys and 5 girls) selected from an institute of science education for gifted students in a university. The scientifically gifted candidates, targeted in the study, were selected based on an entrance examination which is held once a year, documentations, references, written tests, and interviews, in order to prove their talent in science. Thus, they were given the opportunities to receive various learning experiences in the institute of local university, during weekends and specific seasons, to develop knowledge, process skill and scientific attitude. Most of them didn't have any prior experiences in studying science using Scratch programming, and they preferred the subject of science than other subjects.

3. Tests

For the quantitative data analysis for effects of the STEAM lessons, three kinds of test instruments (Yoo *et al*., 2011; Jin & Son, 2011; Jang & Shin, 2009) were used in this study (Table 1). Each test instrument was subdivided into several characteristics representing the main purpose of the instruments, and the participants took pretest and posttest consisting of Likert scale with the instruments (Table 1), for 40~60 minutes in entirety. The higher scores for creative personality, creative problem solving ability, and scientific attitude indicated stronger inclination in the specific fields of science.

The instrument to test creative personalities of the gifted candidates was developed at the national level; it has 6 characteristics and 27 items (Yoo *et al*., 2011). KEDI (Korean Educational Development Institute) developed as a national instrument to objectively measure the abilities for the selection of gifted student candidates, and the authors chose this method due to the age and disposition of the participants in this study.

Table 1. Overview of instruments used in this study

Instruments	Characteristics	Number of items		Response format
Creative personality	Task commitment	5	27	4 Likert scale
	Curiosity	5		
	Aesthetic appreciation	5		
	Intellectual openness	4		
	Independence	4		
	Risk sensitivity	4		
Creative problem solving ability	Knowledge · thinking skills · techniques of comprehension and mastery in a specific field	5	20	5 Likert scale
	Divergent thinking	5		
	Critical · logical thinking	5		
	Motivational factor	5		
Scientific attitude	Curiosity	3	21	5 Likert scale
	Open-mindedness	3		
	Critical-mindedness	3		
	Cooperation	3		
	Voluntariness	3		
	Endurance	3		
	Creativity	3		

Meanwhile, another instrument of checklist type was used to figure out the improvement in creative problem solving ability of gifted students, which was conducted as a self-reported measure using creative problem solving (Jin & Son, 2011). The instrument was selected based on previous studies regarding the information education of Korea, and it is a self-reported checklist for detecting the behavior characteristics. The last test instrument consisted of 18 positive and 3 negative questions for testing 7 characteristics of scientific attitude; its Cronbach's α was .87 (Jang & Shin, 2009). It was chosen according to the purpose of verifying whether the developed teaching and learning program, dealing with one content of Life area in elementary science, can effect on the scientific attitude. The significance of any difference in the results between the pretest and posttest scores was analyzed using SPSSWIN 22.0.

4. Semi-Structured Interviews

One of the authors of the study interviewed all of the students, who participated in the STEAM lessons,

Table 2. Questions of post-interviews

No.	Categories	Main questions	Supporting questions
1	Understanding of lessons	Were the learning contents difficult to you?	Why do you think so?
2		What were your strategies to understand the learning contents?	Did you connect to contents of other subjects?
3		Where can you apply what you learned?	How can you explain what you learned?
4		What do you want to know more?	Why do you want to know them?
5		Do you understand the learning contents overall?	How do you organize to remember various learning contents?
6	Creative design	What were you concerned about when you processed?	Why were you concerned about that part?
7		How could you solve the problems?	Who is the best member contributed to your project for solving the problems?
8		What was your aim of ideas?	When did you experience it?
9		Why did you design in this way?	Did you study design enough during classes going by?
10		How did you design of the project?	If you carry it out now, do you think that it is possible?
11	Emotional touch	How did you feel when the lessons started?	Why did you feel such like that? You don't need to talk about your personal stories.
12		Did you immerse in the lessons easily?	What was the reason to immerse in the lessons?
13		How do you feel after the lessons?	Do you want more lessons in the same way of this?
14		Do you have any experience to express your emotions in activities of the lessons?	Did you expect to experience those emotional touch?
15		Have you ever thought about science ethics in activities of the lessons?	When, and Why did you think so?

using a semi-structured group interview technique and questionnaire (Jeong, 2013, Table 2).

The interviews for 10 groups, consisting of 2~4 members per group, were held after finishing the program (10-minute average duration). This was achieved by using whole sampling to identify the individuals who understand the STEAM lessons. The interviews were transcribed, and the transcripts were examined for statements related to the key units in this study. The authors tried to overcome the weaknesses of quantitative approaches, by using the methods of both semi-structured interview and survey through questionnaires. These were applied to the scientifically gifted students previously, in Jeong and Sohn's Study (2013). We extracted identical attributes by reviewing the results on the transcripts; this technique was used to extract significant statements based on phrases and sentences from the participants' responses, which we made into fundamental structures for organizing constructive meanings applicable to theme, theme clusters, categories (Shosha, 2014).

III. Results and Discussion

1. A Strategy of STEAM Lessons using Scratch Programming for Science Education

The STEAM Lessons (Table 3) were organized to improve diverse abilities of learners by fusing Scratch programming to science education at the elementary science-gifted student's level. Also, they followed STEAM educational philosophy, in which the engineering or technology can be applied to practically connect the learning principles with science and mathematics, by incorporating emotionally touching experiences (Ministry of Education and Science Technology [MEST, Korea], 2011).

According to qualifications for application of Scratch programming to lessons (Lim, 2012), we tried to make the STEAM program to meet the requirements, which were important for authentic integration between detailed scientific contents and computer programming. The authors considered the following qualifications in developing the STEAM lessons in this study: (1) making products as the results of simple programming works, (2) contents including various multimedia, (3) possibilities for manipulative activities using Scratch board, and (4) value of collaborative works.

Table 3. Contents and scope of the STEAM lessons using Scratch programming

Grades	5~6	
Related subjects	Science, Practical Arts, Mathematics, Arts, Society, and Korean	
Main concepts	Small Organisms, Ecosystem	
Learning methods	Scratch programming	
Learning environment	Preparation for using personal computers	
Activity summary	Based on learning contents regarding appearance, characteristics and environment of small organisms, learners design and build virtual space for small organisms through programming. Each team performs creative design by self-directed learning. Eventually, learners achieve to realize their own biosphere as STEAM products.	
Objectives of STEAM lessons	Learners can make a biosphere using Scratch programming for 'Small organisms' depending on an environmental habitat. · To understand differences of life style of organisms depending on their environmental habitats · To realize a creative and diverse Scratch programming · To review scientific concepts related to 'The worlds of small organisms'	
Conditions	· To design a biosphere using Scratch programming regarding small organisms with cooperation of your team members. · To make a quiz using Scratch about what you learned	
Main learning scope	Small organisms	Scratch
	· Appearance and characteristics · Habitats · Biological/non-biological factors	· Animation effects · Output of talks · Using variables

The developed STEAM lessons consisted of four steps, such as analysis, designing, building, and assessment, for solving a problem related to small organisms and their ecosystem (Table 4).

Students were engaged in creative programming project to deepen their understanding of scientific knowledge through learning experiences in the STEAM activities. The STEAM lessons not only included science activities related to biology, ecology, environmentology, life science, and Earth science, but it included computer activities from programming and ICT (information and communications technology). In addition, some factors from mathematics and liberal arts were connected to the STEAM lesson design. It was fundamentally important to understand STEM education programs in their full complexity and contextuality, to engage with the diversity of perspectives, experiences, and values (Greence *et al.*, 2006).

An example of teaching plan that was applied in this study revealed that 7 class hours were enough to have children acquire ways of controlling programming as well as gaining scientific knowledge, as shown in

Table 4. Problem solving process in the STEAM lessons using Scratch programming

Creative Design-based problem solving process		Contents				Inquiry skills		
		Science	Technology/ Engineering	Mathematics	Arts	Science	Technology/ Engineering	Mathematics
Analysis	Problem situation	Designing and making a biosphere for small organisms				Recognizing of a problem		
Design	Collecting data	· Appearance and characters of small organisms	· Understanding of Scratch programming			Observing	Characteristics and use of information devices	
	Consultation idea	· Choosing the environment living small organisms	· Consultation how to design	· Consultation how to put organisms	· Consultation design of surrounding environments	Classifying, Communication	Exploration and selection of information	Number and operations, Probability and statistics
	Design	· Design the environment condition	· Design how to realize it	· Design shapes of the biosphere		Measuring, Predicting, Transforming data	Exploration and selection of information	Geometry
Build	Build	· Considering the ecosystem factors	· Making the biosphere with Scratch programming	· Setting numbers in programming for position and movement of organisms	· Considering esthetic factors	Transforming data	Life using data	Problem solving
	Test		· Testing the result of Scratch programming				Characteristics and use of information devices	
	Improvement	· Analysis of pros and cons	· Checking problems in programming	· Adjustment of position and movement	· Considering social and moral matters	Interpreting data, Inferring	Characteristics and use of information devices	Problem solving
Assessment	Presentation and assessment	· Scientific communication	· Presentation the result of programming and sharing on Scratch web site		· Mutual evaluation of pupils through discussion	Interpreting data, Drawing conclusion	Life using data	

Table 5. Teaching plan of the STEAM lessons

Class	Time (min)	Step	Learning topics	Learning contents	Learning methods	Assessment methods
1	40	Problem situation	To make preparations to design the biosphere for small organisms	-The appearances and features of small organisms -Habitats of small organisms -Basic Scratch programming -Methods of data collection	Whole class, Individual work, Group work	Teacher's observation evaluation, Performance assessment
2	40	Collecting data				
3	20	Consultation idea				
	20	Design				
4~5	80	Build	To realize the biosphere using Scratch in virtual worlds	-The elements of ecosystem -Scratch programming	Group work	Teacher's observation evaluation, Performance assessment
6	20	Test				
	20	Improvement				
7	40	Presentation and assessment	Presentations on the STEAM products	-Presentation and discussion	Whole class	Products evaluation, Peer evaluation

Table 5.

Seven class hours were allocated to each stage of analysis (1 class hour), designing (2 class hours), building (3 class hours), and assessment (1 class hour). Throughout the whole STEAM lessons, students took a variety of activities both individually and collaboratively. Teacher's main role was to facilitate more creative and effective growth of students at their planning and application stages, through encouragement.

As can be seen from Table 6, the developed STEAM lessons using Scratch programming received mostly positive reviews from both the science and computer educators. 'The concepts of STEAM lessons' received the highest index of content validity (92.08), whereas 'Presenting the problem situation' received relatively low index of content validity (88.75). The result of CVI featured positive reviews for the intention of the STEAM program as an integration of two different disciplines. It is also inferred that both science and computer educators were concerned of the limitation in learning science through virtual world, although the STEAM lessons adopted learning materials related to surroundings of elementary students.

2. STEAM Lesson's Impact on Student's Creative Personality and Scientific Attitude

Table 6, Table 7, and Table 8 show the application results of STEAM lessons using Scratch programming on the development of creative personality, creative

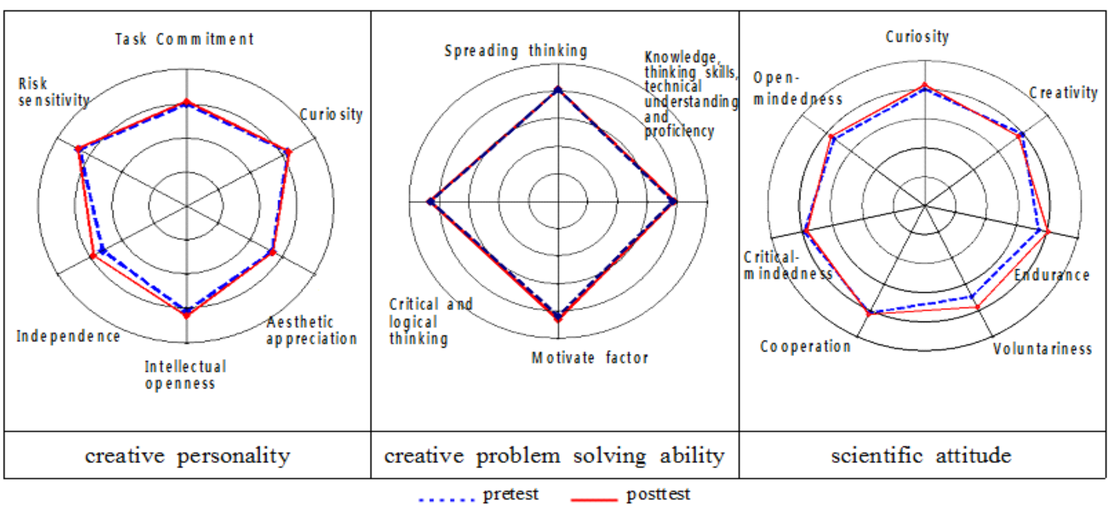

Fig. 2. Comparing the results of pretest and posttest

problem solving ability, and scientific attitude, respectively. The significant differences between pretest and posttest are shown on the creative personality and scientific attitude (p<.05), while it was not significantly different on creative problem solving ability.

As Fig. 2 is shown, the criterion was from raw score, and the polygons of posttest results connected points of the sub domains, which are a bit expanded to outside of the polygons of their pretest.

The sub domain, which had the highest points of mean in creativity personality, was 'Risk sensitivity' in both pretest and posttest, and the most improved sub domain was 'Independence'. In the creative problem solving ability test, the results of pretest and posttest were nearly equal though it demonstrated that the participants' self-rating mean was over 4 in the sub domains of both pretest and posttest, irrespective of taking the STEAM lessons. As can be seen from scientific attitude polygon, the domain of the highest score was 'Curiosity' marked as 4.33, but the dramatic changes were shown in 'Voluntariness' and 'Endurance'. It can be inferred that the findings of improvement or at least maintenance in all domains of creative personality, creative problem solving ability, and scientific attitude, showed that the STEAM lessons positively affected in the development of the students.

Table 6 shows the effects of the STEAM lessons on creative personality, based on the results of the survey.

Average of posttest results for every domain was slightly increased in overall, compared to the pretest; 'Independence' domain especially had significant differences. The significant change in total score indicated that the STEAM lessons positively affected on creative personality of the participants. This finding is similar to previous studies; for example, Kim and Son (2012), Kwon *et al*. (2012), integrated programs positively affecting on creative personality of gifted students. It is inferred that student-centered activities make learners to improve their independence through STEAM lessons.

As you can see in the Table 6, scores for risk sensitivity was higher, while independence score has a significant difference. Risk sensitivity is a tendency to progress works by students' desire, even when they feel possibilities of failure; and the students had the attributes of encountering new conditions and attempting to do some difficult works. Independence, one of elements of creative characteristics, means the inclination to do works by oneself, that irrespective other peoples' thoughts and evaluation (Kim & Son, 2012). The

Table 6. The effects on creative personality

Domains	Test	*M*	*SD*	*t*	*p*
Task commitment	Pretest	3.24	.620	−.883	.379
	Posttest	3.30	.643		
Curiosity	Pretest	3.38	.601	−.377	.707
	Posttest	3.40	.592		
Aesthetic appreciation	Pretest	3.00	.880	−.185	.854
	Posttest	3.02	.948		
Intellectual openness	Pretest	3.30	.681	−1.465	.146
	Posttest	3.40	.676		
Independence	Pretest	2.95	.729	−2.316	.023*
	Posttest	3.16	.814		
Risk sensitivity	Pretest	3.49	.574	−.427	.670
	Posttest	3.52	.574		
Total	Pretest	3.22	.715	−2.289	.022*
	Posttest	3.29	.740		

*p<.05

science-based STEAM lessons regarding 'Weather and our life' in elementary school studied by Lee and Kim (2012) was effective for developing creative thinking and personality in total score, although the score of independence was not significant. Personality characteristics associated creative individuals can be divided into two patterns, and independence of thought belongs to listening to one's inner voice (Selby *et al*., 2005). From the point of view, it is inferred the participants of this study used more convergent thinking than divergent thinking when they generate ideas. Furthermore, we think the score of independence was increased because the developed program was helpful for the science-gifted students to be passionate and objective about their work.

The result in Table 7 indicates that the effect of the STEAM lessons did not significantly increase the creative problem solving ability, during the period of this study.

In previous studies, Kim and Kang (2007) and Son (2009) indicated that scientific and creative problem solving abilities are easily influenced by diverse features of children, such as aptitude or inquiry level, and children in this study indicated that creative problem solving ability was not improved by the STEAM lessons used. However, unlike Song *et al*. (2008), and Ryu and Lee (2012), who found that the ability of creative problem solving can be improved through Scratch programming, it seemed that the focus of STEAM programs for designing is an important matter indeed.

It was inferred that enough learning periods were necessary to improve creative problem solving ability, because the participants of this study took classes for only a short period of time. In addition, the pre-test score was high to start with, and it could be the reason of not producing a significant gap between pre-test and post-test, although the mean score was increased slightly. To improve creative problem solving ability of students, projects with a high level of difficulty that can take a long time could be effective. Another possibility is the limitation of STEAM program. Thus students couldn't mainly focus on flexible, dynamic and descriptive uses of creative problem solving ability. Furthermore, process using programming to create a product can be the reason of result. When you apply scratch programming in your lessons, you need to consider pros and cons of lessons using computers which are different from hands-on activities having opportunities to solve problems creatively with learners' various approaches. Treffinger (1995) also suggested that several metacognitive and task appraisal skills are required for using creative problem solving effectively, so it could be helpful to emphasize the skills in the STEAM lessons.

According to Table 8, the STEAM lessons were effective on scientific attitude of gifted students. Since it is interesting to play with Scratch programming, the students were motivated to learn without fear of failures, which it might have educational value. Similar to the findings of previous studies (Choi & Hong,

Table 7. The effects on creative problem solving ability

Domains	Test	*M*	*SD*	*t*	*p*
Knowledge · thinking skills · technical understanding and proficiency in certain areas	Pretest	3.84	.971	−.620	.537
	Posttest	3.89	1.101		
Spreading thinking	Pretest	4.05	.776	−.284	.777
	Posttest	4.07	.809		
Critical · logical thinking	Pretest	4.28	.705	−.267	.790
	Posttest	4.30	.764		
Motivate factor	Pretest	4.16	.713	−1.531	.128
	Posttest	4.28	.715		
Total	Pretest	4.08	.812	−1.306	.192
	Posttest	4.13	.874		

2013; Lee & Lee, 2013), STEAM lessons affirmatively affected on the scientific attitude of children. In particular, there were significant differences in the domains of ‘Voluntariness’ and ‘Endurance’. Hence, we need to concentrate on what Jang *et al.* (2013) mentioned in their study of scientifically gifted students, who were distinguished from general students because of the characteristics of task commitment. Voluntariness and endurance are thought to be correlated with aptitude of gifted students, who were immersed into their task during execution. This has implications that the students are able to endure failures or errors, in the process of completing a challenging task that they are interested in. As Beghetto (2008) has pointed out, when the students are motivated to learn against the fear of failures, it raises questions about the students' ability to be immersed into the task. Scratch programming education has potential effects on improving the level of learning-flow for elementary students, in accordance with the findings of Ahn *et al.* (2011).

We can inferred a possibility to be associated between creative personality and scientific attitude through the result of improvements in the two domains. The STEAM lessons regarding small organisms using Scratch programming can be influenced students' affective aspects positively, so it could be attributed to improve the two domains. Park and Lew (2011) found significant positive relationships among self-esteem, creative personality and creative thinking, indicating that the effects of self-esteem on creative thinking were mediated by creative personality. Schiever (1985) has reported that overexcitement and characteristics of creatively gifted were arranged to psychomotor, sensual, imaginational, intellectual and emotional behaviors. For an example, heightened awareness of and sensitivity to the environment or rapid insight into cause-effect relationships may be useful characteristics to assist scientific thinking and behaviors. On the other hand, the results not to be improved creative problem solving ability indicate the domain was not relevant to a certain factor which affected creative personality or attitude of the students.

3. Characteristics of the Responses to STEAM Lessons

Table 9 shows the responses which were collected from all of the interviewees.

Table 8. The effects on scientific attitude

Domains	Test	*M*	*SD*	*t*	*p*
Curiosity	Pretest	4.21	.795	−1.343	.183
	Posttest	4.33	.750		
Open-mindedness	Pretest	3.95	.966	−1.195	.236
	Posttest	4.06	.958		
Critical-mindedness	Pretest	4.14	.697	.618	.539
	Posttest	4.08	.923		
Cooperation	Pretest	4.26	.711	−.563	.575
	Posttest	4.31	.778		
Voluntariness	Pretest	3.76	1.119	−2.566	.012*
	Posttest	4.09	.900		
Endurance	Pretest	3.97	.939	−2.106	.038*
	Posttest	4.22	.750		
Creativity	Pretest	4.17	.590	1.051	.296
	Posttest	4.06	.811		
Total	Pretest	4.06	.860	−2.520	.012*
	Posttest	4.16	.845		

*$p<.05$

Table 9. The results of the semi-structured interview

Categories	Themes	Meaning units	Rate (%)	
Understanding of lessons	The level of difficulty	· Hard: inexperienced, unfamiliar of programming, required accuracy and complicated · Normal: acclimatized · Easy: Not difficult contents, interested in organisms and simple	8.65	32.69
	What you learned	· Features of organisms · Sorts of specific organisms · Scratch programming	5.77	
	Strategies to explain what you learned	· Making learners be curious · Showing finished products of Scratch · Showing examples of organisms · Describing how to do · Giving opportunities to experience	3.85	
	What you want to know more	· Scientific knowledge: biology, organisms and history of science · Computer programming: Other programming tools and 3D realization	7.69	
	Direction of application	· Educational application: For smart education, programming education, production of useful games, presentation and assignments for school · Hobbies: For new challenges and amusement	6.73	
Creative design	Difficulties and troubles	· Design: Choosing theme, selecting of massive data · Build: Errors of scripts, a temptation of internet games or webtoons, technical mistakes, lack of understanding to operate · Affective matters: Burden and confusion when you met unexpected problems · Peer problem: A disagreement of opinion, an imbalance tasks among team members	11.54	40.39
	Strategies to solve problems	· Learning by repetition: Using functions as copy or paste and substituting figures · Collaborate works: Working together, sharing responsibility and teaching each other · Emotional control: With concentration, calmness, challenge spirit and so on	11.54	
	Aims of ideas	· Science: detailed descriptions of organisms · Technology: Collecting and editing proper data · Engineering: Changing screens and making quiz · Arts: Harmonious factors · Mathematics: Configuring of random numbers	5.77	
	Methods	· Getting ideas from Scratch projects posted on the official website of Scratch · Reference to books of students' program guide, Scratch programming, biosphere and biology · Googling from the websites of organisms · Modifying plans partially in build stage · Catching a sudden realization	11.54	
Emotional touch	Views of integration between science and computer education	· Positive: Thinking to play with computers or to be free from prejudice that you should take science classes in a laboratory only · Negative: Awkward and ill-assorted because never seen it before	2.88	26.92
	Feelings about the lessons	· Before the lessons: Excited and distinctive · After the lessons: Pleased, relieved, interested and challenging	9.62	
	Science ethics	· Positive: Collaboration, abilities of self-control and minds for precious organisms · Negative: Controlling from unnecessary and incendiary data while searching information	5.77	
	Strength	· Opportunities to demonstrate creative ideas through self directed, autonomous and hands-on project. · Connection with various subjects like computer, life science, technology, math, arts, ethics, etc. · Sharing projects beyond classroom · Economy in expenditures	5.77	
	Weakness	· Restricted comparatively small-scale screen of programming tool · Time limit for a presentation · Risk of conflicts in team activities	2.88	

The fragments from transcriptions of the interview were used as units, which were categorized into 3 domains and 14 themes, by the framework of semi-structured interview questions. Through specific investigation activities, students learned scientific knowledge such as features and species of organisms. The following is a comment from a participant: “I had indeterminately imagined that ants depend on dewdrops for main food or growth, because of exaggerated descriptions from fairy tales. But, I certainly realized that ants are omnivores. I learned about this by virtually searching for ants' food on the internet.” Furthermore, the interviewee added by saying that the programming design activities were helpful in improving her programming skills.

Although many of the participants didn't have the experiences to learn programming before the STEAM lessons, they seemed to absorb the new technology even through the high level of difficulty that they encountered. When students encountered sudden problems at the designing or building steps, repetitive trial-and-errors were basic and frequent way to solve them. A student commented, “It was difficult at first, but it became much easier by consistently trying.” Students efficiently made achievements through discovery, and their learning relied on heuristic approach. This result is in agreement with those of Lee and Han (2008), who found that the group applied to the web-based system of discovery learning model achieved higher academic performance. Even if there are limitations to generalize these results to all students, since only the gifted students were scientifically involved in this study, we still need to consider the infinite potentials of students around the world who can rapidly absorb and apply the digital contents.

Noh *et al*. (1999) found that cooperative learning enhanced the ability to set up strategies for accomplishing cooperative work. Such response was captured by a student of this study, who responded as follows: “When my colleague was searching for information on the internet, the other colleague and I were designing to change the screens with Scratch programming. We cooperated with each other.” Helping each other in the context of lesson could be a powerful and educational solution in solving problems or establishing efficient strategies. For example, students organized shared accountabilities by themselves, ultimately for the achievements of collaborative goal.

The difference between traditional science class and STEAM lessons using computer programming was recognized when discussing the usefulness of programming during interviews. The followings are the comments by participants: “Programming itself was interesting. In contrast to the usual lessons of listening to teachers' lectures, designing and building with my own ideas was amusing.”; “It is different from science classes without using computers, because people from diverse regions from all over the world can see my project, beyond this classroom.”

The students’ responses indicate that they were aware of the advantages of using technology in their class, because they experienced self-directed learning, collaborative work, and idea sharing. This was similar to the responses in the study by Lim and Jeong (2004), who found that web-based STS instructional model was beneficial in studying biology.

IV. Conclusions

This study developed the STEAM lessons by using Scratch programming for teaching ‘Small Organisms’ in the subject of elementary school science and was applied to scientifically gifted students. As a result, it demonstrated effects of the STEAM lessons on creative personality and scientific attitude. The STEAM program was effective, and it provided insight into teaching approaches to integrate more than two different disciplines when students need to increase their interest in science or to facilitate potential abilities. Therefore, an integration of life science and programming can be an educational strategy, as an effective means for STEAM lessons. It consists of the process of understanding the biosphere for small organisms by programming, and it could complement factors of technology and difficult tasks of engineering to be adopted in STEAM education at the elementary school level.

Encouragements from the teachers regarding the students' collaboration with peers and achievement of common goal were important in overcoming the problems (Zollman, 2011) they encountered during the process of STEAM problem solving; this shows that caring and communication are essential in STEAM education (Park *et al*., 2012). In addition, teachers who will plan and teach STEAM lessons using computer programming in their classes should consider using STEAM application and understand the programming depending on different levels of the learners (Lee & Lee, 2008; Basham & Marino, 2013). Future studies will be required to provide more practical results of STEAM learning contents and methods of applications in school. It is suggested that training of programming is needed as well, for the teachers who have important roles in providing suitable lessons to their students.

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