Development and Application of STEAM Based Education Program Using Scratch: Focus on 6th Graders' Science in Elementary School

JungCheol Oh, JiHwon Lee and JongHoon Kim

Abstract For this study, we reviewed theoretical background of STEAM education and domestic and international case studies in STEAM education. By doing so, we developed and applied the STEAM Education Program through the use of Scratch. This program is designed for the 3rd ("Energy and Tools") and 4th ("Combustion and Extinguishing") lessons of 6th graders' science in elementary school. As a result, the creativity index and positive attitude about science of the students who went through the researched program increased with meaningful difference compared to that of the sample population. The result of this study shows that 'The STEAM Education Program,' using Scratch, can improve creativity. And it is sure that it brings positive changes for the Science Related Affective Domains.

Keywords STEAM · Scratch · Creativity · Scientific attitude · Fluency

1 Introduction

In the present century, science and technology has combined with human life in a more humane and artistic way than ever before. The iPhone, introduced by Steve Jobs, an artistic engineer, is a good example of how science and technology combine with human life in a human-friendly and artistic way. This societal

J. Oh · J. Lee · J. Kim (✉)
Department of Computer Education, Teachers College,
Jeju National University, Jeju, Korea
e-mail: jkim0858@jejunu.ac.kr

J. Oh
e-mail: lov0502@naver.com

J. Lee
e-mail: torchere@naver.com

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demand has been reflected in the educational community, and the Ministry of Education and Science of South Korea has established various educational strategies for educating students to create fused talents [1].

In 2009, Partnership for Twenty first-Century Skills, an organization in the U.S., suggested essential skills that students need to learn and master in order to succeed in the twenty first century [2]. The organization suggested that students should learn such skills as creativity, critical thinking, problem solving, communication, and collaboration through art, mathematics, science, economics, and history. That is, learners need to develop the ability to fuse diverse skills holistically based on creativity to be able to adapt to the rapidly changing society of the twenty first century and to get ahead of the times.

The government stressed the importance of STEAM education to train people with such holistic talents and is now preparing various strategies for educating them. This study aimed to develop a STEAM education program that can be applied in the field, using technology and engineering Scratch, which can be easily accessed by learners in the aforementioned context.

2 Theoretical Background

2.1 Need for and Definition of STEAM

Smart STEAM stands for Science, Technology, Engineering, Arts, Mathematics and means learning the fused knowledge of various fields. The effort to find the cause of the economic crisis in the U.S. led to the identification of the decrease in the academic performance of mathematics and science learners as the cause [3, 4]. To address this problem, STEAM aims to promote the learners' motivation for learning and to educate people so as to help them become capable of solving multidisciplinary problems.

Regarding STEAM fusion education, Yakman (2008) presented a pyramid model consisting of several levels, from continuing education to the classification of the detailed study contents and stated that the interdisciplinary integrative level was appropriate for elementary school education [5].

Although in most of the current STEAM education programs computers serve only as auxiliary tools, in this study, it was used as a main activity in the fusion education for applying and utilizing the science lessons. That is, the students can clearly understand the lesson contents and can see the process and result of making programs real-time. Thus, the possible errors in the real-life experiment can be reduced, and the students can have opportunities to apply and express the scientific principle in various ways using divergent and creative methods, without temporal and spatial restrictions.

3 Design and Making of the Steam Education Program

3.1 Design of the Stages of Steam Teaching and Learning

Study stages were established as follows to develop the STEAM education program using Scratch, and to apply the developed program. The study was conducted for 6 months, according to the study stages. The teaching and learning stages for science and technology presented by Miaoulis (2009) and the creative comprehensive design stages for people with inter-disciplinary talents presented by Korea Foundation for the Advancement of Science and Creativity (2011) were reviewed to design the stages for STEAM teaching and learning that will be applied to the education field.

Table 1 shows the stages for creative design presented by Korea Foundation for Advancement of Science and Creativity when it introduced the concept of creative comprehensive design education. The foundation explained that the stages are the characteristics of the new STEAM education.

Based on this, six stages of STEAM teaching and learning Table 2 were determined, and the program was conducted. In particular, during the "making or synthesizing" and "testing" stages, creative work was accomplished by frequently making and modifying the activities. Thus, continuous testing and feedback are required.

Table 1 Stages for creative design presented by Korea foundation for advancement of science and creativity

1. Setting of objective	2. Planning and designing	3. Analysis of design	4. Making	5. Test	6. Evaluation

Table 2 Stages of STEAM teaching and learning

1.	Experiencing priming water for an idea	Define the issues and experience priming water for an idea related with the issue
2.	Coming up with an idea	Create various ideas and share them with collaborators
3.	Planning and design fusion	Establish a plan for materializing the idea, and make a design by fusing related studies
4.	Making or synthesizing	Make or synthesize works based on the idea using scientific, technological, engineering, and artistic methods
5.	Testing	Test, and Feedback or modifying
6.	Evaluation	Inter-collaborators' evaluation, and refinement of the idea through evaluation

3.2 Formulation of the Steam Education Program

The units were constructed, using the stages of the STEAM teaching and learning activities and the categorized science experiment themes. Activities for making games using Scratch were included considering that the learners are elementary school students, who are highly interested in games, and that various artistic activities, such as plotting a story, selecting background music, and drawing characters, are complexly performed for game creation.

At the "experiencing priming water for an idea" stage of each unit, the teachers pre-sent Scratch games to help the learners come up with an idea. At the "coming up with an idea" stage, the learners are allowed to present and discuss the games that they want to make, and by doing so, to share the ideas with one another.

At the "planning and integrative design" stage, the learners are allowed to make a storyboard based on the various science experiments presented in the textbook. Many storyboards can be made, according to the experiment, or only one storyboard can be made in detail. The learners are allowed to make storyboards freely, without restrictions in theme and expression. At the "making and synthesizing" stage, the learners are allowed to formulate "instructions on how to play the game made" based on the storyboard made, and to make games using Scratch.

At the "testing" stage, the learners can modify the game by playing it with their collaborators, and by reviewing it. There was no boundary between the "making or synthesizing" and "testing" stages, allowing the learners to make, synthesize, and review activities whenever they needed to do so, and by doing so, to complete creative works like those shown in Fig. 1.

In addition, the learners can write what they felt through these two stages in "Instructions on how to play the game made." The learners who made a maze game through several stages added mazes to the game by reviewing the game together with their collaborators (Fig. 2) and by completing the final game.

At the "evaluation" stage, the learners can display the games that they made, and can play these, so as to evaluate one another's games. The learners can also refine their ideas by sharing their completed ideas with others.

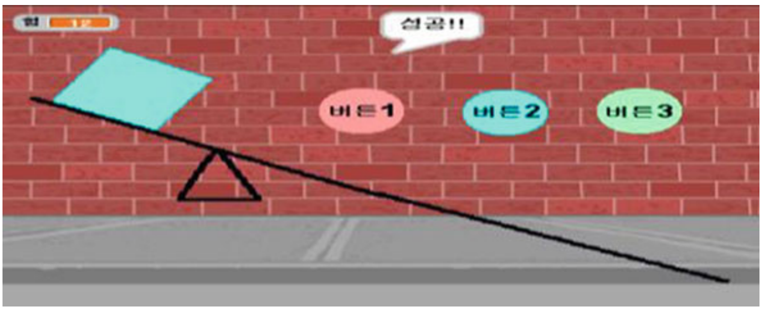

Fig. 1 The game completed after the review with the collaborators, and after modification

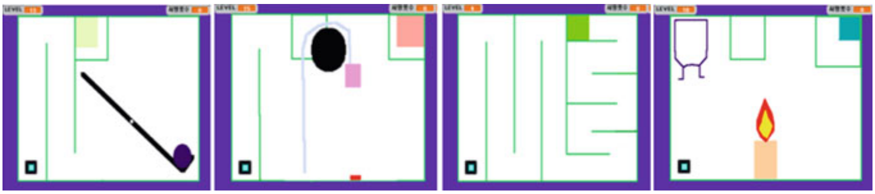

Fig. 2 Games made by other learners

4 Application of the Program and Analysis of the Results

4.1 Study Design and Control of Variables

Two classes in the 6th grade of Elementary School in Jeju City, Jeju Island, South Korea were included in the study (Table 3). The classes were assigned as the experimental and control groups, respectively. For 10 weeks, from the fourth week of September 2011 to the first week of December 2011, the Scratch-based STAEM education program was conducted in the experimental group, on the two units of the science textbook.

As shown in Table 3, a test of baseline creativity and an evaluation of the affective characteristics associated with science were performed in the two groups, and the homogeneity of the two groups was validated. For the control group, a normal science class was conducted as planned.

4.2 Test Tools

The area that this study intended to identify through objective validation after the application of the Scratch-based STEAM education program was the creativity and affective characteristics associated with science. To determine if the creativity had been enhanced, Torrance's TTCT (diagram) Creativity Test Type A was performed before and after the experiment. In addition, "Evaluation System for Affective Characteristics (Attitude) Related with National Science" developed by Hyonam et al. [6] at the Science Education Institute of Korea National University of Education, based on the theory on science-related attitude presented by Klopfer

Table 3 Experimental group

Division	Number of students		
	Male	Female	Total
The experimental group	12	13	25
Comparison group	12	13	25
Total	24	26	50

and the criteria for evaluation items presented by Edward, was used for the test of affective characteristics related with science. Type A consisted of items evaluating the awareness of and interest in science, and type B consisted of items evaluating scientific attitude. For the reliability of the items, the Chronbach alpha coefficients were 0.83 and 0.86 for types A and B, respectively. As both exceeded 0.8, they were deemed reliable.

4.3 Results of the Creativity Test and Interpretation of the Results

To verify the homogeneity of the factors of creativity between the experimental and control groups, the mean of each area of creativity in each group was tested through a *t* test, using SPSS 12.0 for Windows, before the experimental treatment ($p = 0.05$). As shown in Table 4, the significance probability for the creativity index was $p = 0.929$; thus, there was no significant difference in creativity between the experimental and control groups. The other areas of creativity, such as fluency, creativity, abstracting ability, and delicacy, were not significantly different between the two groups as the significance probability was higher than 0.05.

Ten weeks later, the creativity test was performed again on the experimental and control groups. As shown in Table 5, the creativity and originality were significantly different between the groups, with $p = 0.036$ and $p = 0.039$, respectively. In particular, the post-experiment creativity increased by 10.17, and the significance level was remarkably different, with $p = 0.000$ ($p < 0.05$) in the experimental group.

Then, the difference in creativity before and after the experiment was compared within the experimental group and was analyzed. As shown in Table 6, in the

Table 4 Test of baseline creativity

Domain	Class	N	Average	The standard deviation	T	Note that the probability
Fluency	Pre	25	115.32	24.81	−1.619	N.S.
	Post	25	122.72	18.57		0.118
Originality	Pre	25	104.80	25.51	−0.202	N.S.
	Post	25	106.04	23.09		0.842
Abstractness of title	Pre	25	95.44	29.87	0.507	N.S.
	Post	25	90.36	37.30		0.617
Elaboration	Pre	25	94.20	18.45	0.676	N.S.
	Post	25	91.36	14.17		0.505
Resistance to premature closure	Pre	25	99.60	17.60	−0.663	N.S.
	Post	25	101.56	11.88		0.513
Creativity index	Pre	25	105.99	19.25	−0.090	N.S.
	Post	25	106.37	16.15		0.929

* $p < 0.05$, *N.S.* not significant, *N* number of cases

Table 5 Post results comparing

Domain	Class	N	Average	The standard deviation	T	Note that the probability
Fluency	Pre	25	125.52	19.12	−2.225	0.039*
	Post	25	132.96	13.89		
Originality	Pre	25	117.00	25.82	−2.187	0.039*
	Post	25	129.24	22.81		
Abstractness of title	Pre	25	100.64	22.93	0.724	N.S.
	Post	25	95.28	29.65		0.476
Elaboration	Pre	25	91.64	18.45	−0.593	N.S.
	Post	25	93.96	14.88		0.559
Resistance to premature closure	Pre	25	104.28	15.62	1.212	N.S.
	Post	25	99.92	15.19		0.237
Creativity Index	Pre	25	114.29	14.67	−4.104	0.000*
	Post	25	116.54	16.29		

*$p < 0.05$, *N.S.* not significant, *N* number of cases

comparison of the fluency, originality, and creativity index before and after the experiment within the experimental group, the significance probability was less than 0.05; thus, the difference was significant. It was found that Scratch-based STEAM education had a positive effect on the improvement of the fluency, originality, and creativity index.

4.4 Results of the Test of Affective Characteristics Related with Science

The evaluation of affective characteristics developed by Hyonam et al. [6] consists of three categories (awareness, interest, and scientific attitude), and each item is graded based on a 5-point Likert scale. The results of the pre-experiment test showed that compared with the control group, the awareness of science was low (0.548 points), the interest in science was high (0.008), and the scientific attitude was high (0.284) in the experimental group (Table 7).

The post-experiment test showed that the mean of awareness (C) of science in-creased by 0.168, the interest in science (I) by 0.231, and the scientific attitude (A) by 0.281. In particular, compared with the control group, the awareness and interest of the experimental group considerably increased. The results showed that the Scratch-based STEAM education program had a positive effect on the affective characteristics related with science in the experimental group.

Table 6 Results of the test of creativity by time point

Domain	Class	N	Average	The standard deviation	T	Note that the probability
Fluency	Pre	25	122.72	18.57	−3.556	0.002*
	Post	25	132.96	13.89		
Originality	Pre	25	106.04	23.09	−5.705	0.000*
	Post	25	129.24	22.81		
Abstractness of title	Pre	25	90.36	37.30	−0.571	N.S.
	Post	25	95.28	29.65		0.573
Elaboration	Pre	25	91.36	14.17	−0.732	N.S.
	Post	25	93.96	14.88		0.472
Resistance to premature closure	Pre	25	101.56	11.88	−0.543	N.S.
	Post	25	99.92	15.19		0.592
Creativity index	Pre	25	106.37	16.15	−3.323	0.003*
	Post	25	116.54	16.29		

*$p < 0.05$, *N.S.* not significant, *N* number of cases

Table 7 Results of the test of affective characteristics related with science

Domain	Class	N	Average	The standard deviation	T	Note that the probability
Cognition	Comparison	Pre	25	3.599	0.419	+0.014
		Post	25	3.613	0.351	
	Experiment	Pre	25	3.051	0.366	+0.168
		Post	25	3.219	0.440	
Interest	Comparison	Pre	25	3.293	0.585	+0.003
		Post	25	3.296	0.586	
	Experiment	Pre	25	3.301	0.579	+0.231
		Post	25	3.532	0.615	
Attitude	Comparison	Pre	25	3.081	0.424	+0.231
		Post	25	3.312	0.460	
	Experiment	Pre	25	3.365	0.443	+0.281
		Post	25	3.646	0.661	

5 Conclusions

This study aimed to develop and apply a STEAM education program that can be applied to elementary school education, and to show the effect of the program according to the education for people with integrated talents stressed by the Ministry of Education and Science. Towards these ends, foreign and local studies on STEAM were reviewed, and appropriate subjects and contents that could be applied to the education were selected and combined with Scratch, an educational programming language. In addition, to increase the appropriateness of the program, discussion with and inter-views of experts in schools and colleges were performed during the selection of education contents and the designing of the stages of teaching and learning. Then, the developed STEAM education program was applied to the students for 10 weeks, under the condition where all the possible variables were controlled. The fluency, originality, and creativity index significantly increased in the experimental group, which used the STEAM education program, as opposed to the control group, and the positive answers in the area of awareness of and interest in the affective area considerably increased in the experimental group. These results indicate that the Scratch-based STEAM education program has a positive effect on the creativity and affective characteristics related with science. In addition, the STEAM education program developed in this study has the two following meanings: (1) STEAM education was utilized without interrupting the flow of the units of the science textbook, to allow the smooth progression of the current curriculum; and (2) using the educational programming language, methods of fusing science, technology, engineering, arts, and mathematics to attain what STEAM intends to achieve were presented.

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