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The Influence of Robot-Based Learning on Elementary School Students' Creativity

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Abstract

This study examines the influence of robot-based learning on both male and female elementary school students' creativity. For this purpose, we applied robot-based learning to the official Republic of Korean general education course curriculum, comprised of mathematics, social studies, science and art. A creativity test was conducted twice, both pre and post robot-based learning. The results indicate that robot-based learning increases students' creativity effectively. Furthermore, the creativity of students in the middle and upper grades showed distinct improvement in comparison with that of students in lower grades, regardless of gender. The results of this research are significant because the study investigates the potential for robots to be used as a source of educational media and possibilities for the examination of robot-based learning on elementary school student creativity in a regular education course.

Keywords*: Creativity, Robot-Based Learning, Robot Media, Robotics, R-learning*

1. Introduction

Recently, there has been an increasing interest in teaching methods that are not only fun but also effective for learning. Due to the interest in and the availability of technologies that foster creativity, robot-based learning has been actively adopted as a next-generation teaching method, since 2000 [1].

Robot-based learning includes courses where students assemble robots by themselves or carry out programming to do so. In such courses, students naturally learn to search or solve the given problem with the help of a robot [2]. When there are difficulties in solving the given assignment, students are encouraged to naturally collaborate with their fellow classmates [3].

Learning begins with an authentic task given to students via a robot. That is, the students experience tasks similar to problematic daily life situations. By resolving such problems, students can learn various skills required in the Constructionism Era [4].

Previous research shows that robot-based learning is effective for the development of advanced thinking skills such as problem solving [2], social interactions [5-6], and creativity [7-8]. However, most of the previous research related to robotics in education is descriptive in nature, based on reports of teachers attaining positive outputs with individual initiatives [9-11]. Furthermore, many studies on robot-based learning took place at irregular times, such as during afterschool classes, independent learning courses, or were conducted on a limited and specific subject such as mathematics or sciences [2,5,12-13]. Hence, limitations exist in examining the possibilities of robot-based learning on students in regular education courses and in the choice of subjects.

Accordingly, this research examines how student creativity changes when robot-based learning is applied to general elementary school courses such as mathematics, social

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studies, science and art. Following this, the study obtained objective results based on a student survey.

2. Research Subject

We checked whether there were changes in creativity before and after the robot-based classes using the following questions as a basis for analysis.

How does the learner's creativity change from its state before and after robot-based class?

(1) Is there a difference in creativity between pre- and post-inspection score?

(2) Is there a difference in creativity between pre- and post-inspection score according to gender (boys, girls)?

(3) Is there a difference in the degree of creativity change between pre- and post-inspection score in boys according to grade levels (low, middle, upper)?

(4) Is there a difference in the degree of creativity change between pre- and post-inspection score in girls according to grade levels (lower, middle, upper)?

3. Related Research

3.1. Educational Robots and Robot-Based Learning

An 'educational robot' is a generic term that defines diverse forms of robots that are utilized in educational practices for the purpose of teaching and learning. There exists no discernible objective definition for educational robots, but in most studies, educational robots are meant to indicate 'assembly type robots' like Lego. The term implies that students can learn aspects of the software and hardware by personally handling the robot. Related studies on assembly type robots in education have mainly focused on supporting the teaching of subjects that are closely related to the robotics field, such as robot programming [5].

In contrast, in one study in particular, educational robots are the teacher assistance type. "Teacher assistance type robots" are generally based on diverse contents that drive technology, location moving technology, and voice or video recognition technology [14-15]. They can assist and support teaching and learning in education. For example, PEBBLES (Providing Education by Bringing Learning Environments to Students) developed in Canada is used for teachers and students engaged in distance learning to achieve the same effect as face-to-face learning through remote education [15].

To mention another strand, this study mainly applies various types of assembly robots developed in Korea to examine the changes in student creativity depending on robot-based learning. Robot-based education that utilizes such robots has meaning for robotics as a learning tool [16]. In other words, robot-based education is not merely about teaching students about robots themselves, but is considered an experiential activity for effectively achieving educational goals of a specific curriculum or cross-curricular goals in the regular school curriculum, and has been applied to various areas such as making simple robot shapes, incorporating robots as a resource for storytelling, decorating them, creating special movements, and utilizing them as experimental tools.

In the case of relevant studies, Bers (2002) made a rotor using a Lego robot to improve the technological literacy and design ability of children in lower elementary school grades, and by attaching pictures related to the life cycle of insects on the rotor and repetitively and continuously turning it, Bers enabled them to learn about the concept of the life cycle of insects in a natural manner [17]. That is, the robot's continuous movement was effective in acquiring a scientific concept, and even students who were not good at assembling and programming the robot took an active role in the design process.

Bærendsen (2009) paid attention to the belief that individuals, who are not musically inclined, struggle to have fun creating music, and prepared a class using a robot. Through robot-based learning, students were provided with an opportunity to pleasantly enjoy various music genres even though they lacked musical knowledge or innate ability [18].

Roberto (2010) conducted a storytelling activity using Lego: students were asked to imagine a robot they wanted to make in the introduction without physical limitations. After that, a robot was selected, assembled, and programmed; a story and an environment were created using the robot; and finally, a presentation was made. The researcher observed interactions between learners during this process.

In this way, robot-based education has proven helpful for students to have a positive learning experience in math, music and science and to acquire robot-related functions. This study focuses on the results of preceding studies and inquires into educational effectiveness and the applicability of robot-based learning in the regular curriculum. For this purpose, robot-based learning was applied to general courses including Korean, math, social studies, science, art, music, practical courses, ethics, and physical education. In short, this study is subject-oriented and cross-curricular.

3.2. Creativity and Robot-Based Learning

Creativity is "a skill that figures out a creative solution for a problem" [20], while Gardner (1993) defines a highly creative person as "a person who solves a problem, even if it is unfamiliar at first, with the method that is acknowledged in the end, designs products, and defines new questions in a specific field" [21].

The elements comprising creativity are diverse for every scholar; Guildford (1967) divides human thoughts into convergent and divergent thinking and considers that the elements comprising creativity consist of susceptibility, fluency, flexibility, originality, elaboration, and reconstitution [22]. Torrance (1962) considers that the elements comprising creativity consist of fluency, flexibility, originality, imagination, and elaboration [23]. Jeon (2008) divides creativity into fluency, originality, openness, and sensitivity [24].

The elements of creativity, as explained under a classification established by Jeon (2008) [24], are as follows: Fluency, one of the elements of creativity, is a quantitative ability related to an abundance of ideas that can offer as many ideas or solutions as possible in a certain situation. Originality is an ability to produce rare, novel, and unique ideas or solutions that are differentiated from conventional ways of thinking. Openness refers to an open state or tendency where human's attitude, thinking and experience and *etc.* freely go in and out of space and time without being tied down to conventional thinking, exchanging and inquiring into new possibilities. Sensitivity means sensitively showing interest to various kinds of information obtained from surroundings through five senses, expanding into and exploring new areas through it.

Meanwhile, the purpose of incorporating robots into education is to encourage unique ideas or imagination, and to teach students to tap into what they are thinking in order to allow ideas and creative vitality to manifest. With regard to this, Bers (2009) conducted a study on robot creative activity and creativity development where learners engage in creative activities based on what they have imagined and what they want for themselves. Bers (2009) states that students construct new ideas through repeatedly sharing thoughts with other people and reflecting on them. On top of that, Bers (2009) suggests an actual situation, in which an animal, like a squirrel, messes up a tulip garden, to students in lower elementary grades, and gives them the task of designing, assembling and programming a robot dinosaur and allocating it to the garden as a creative solution. As a result, the students were not proficient in Lego assembly and the abstract activities of programming, but took an active part in the design activity [17]. In other words, utilizing robots in education is effective in encouraging learners to react creatively and actively as an alternative to existing static classes.

4. Robot-Based Learning Program

4.1. Program Development Process

The robot-based learning program was developed after going through the four stages shown in Table 1. First, the basic direction of the robot-based learning program was determined: to accomplish curriculum goals based on experience centered activities, such as robot assembly and movement control, and to focus on developing student creativity. Second, subjects and the curriculum that were applied with robot-based learning were analyzed. Class teachers selected subjects and units that were judged to be appropriate for the application of robot-based learning, considering the age and characteristics of their students. Third, the content of the selected subjects was analyzed and reorganized, and the robot-based learning program was developed. Furthermore, robot-based learning tasks were devised to develop the sub-factors of creativity, fluency, originality, openness, and sensitivity [24]. Lastly, the developed program was introduced to actual classes after review and revision by relevant experts.

Table 1. Program Development Process

Order	Development process of robot-based learning program	Participants
1	Determine the basic direction of education program	Researchers
2	Select subjects and curriculum to apply the robot-based learning program to	Researchers, teachers
3	Reorganize the education process and develop the education program	Teachers
4	Review and introduce the program	Research participants, teachers

4.2. Cases of Program Development

In this section, a robot-based learning case, which was developed while undergoing this study, is proposed to provide further understanding. Table 2 shows “Harmony of Light and Colors,” a unit included in the 6th grade art textbook, which has been reorganized to incorporate robot-based learning.

The “Harmony of Light and Colors” unit aims to realize various design elements and principles concerning light and unique expressions using light. To accomplish these goals, a class was arranged to discover the beauty created with light using a line tracer robot. Here, a line tracer refers to ‘an autonomous robot that detects and follows a line’: an infrared light sensor attached to the robot senses black or white lines and the robot drives along these lines.

In this class, the robot was not simply a tool to be mechanically assembled or driven, but a piece of creative art. Students were expected to experience creative and flexible thinking through the robot [25].

Table 2. Basic Information of Robot-Based Learning Introduced in this Study

Subject	Art	**Area**	Visual culture
Unit	Harmony of Light and Colors	**Subjects**	6th graders
Study subject	Draw a picture of light using a robot		
Study object	To express a world made with light using a robot.		
Learning group	Whole learning→ Cooperative learning→ Whole learning		

Tables 3 and 4 include information on activities that are carried out in the different stages of robot-based learning. First, students assemble and shape the line tracer, and embody the robot's movement through simple programming. Then, a light source is attached to the robot, and pictures of how the robot moves are taken. After taking the pictures, students inquire into the principle and beauty of design elements in the process of appreciating their own works of art.

Table 3. Information of Robot-Based Learning Activities by Stages

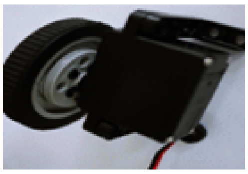
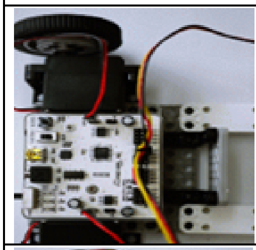
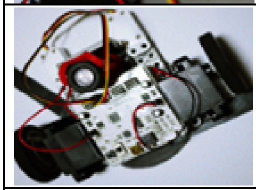
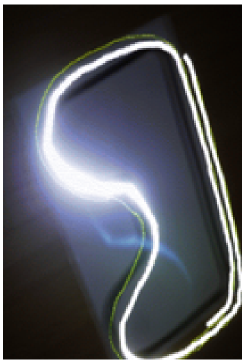
	[Activity 1.] : Making a movable robot body ① Prepare line tracer robot parts. ② Organize and arrange robot parts. ③ Make a movable robot body by putting wheels on it.
	[Activity 2.] : Attach a sensor that senses black lines ① Attach the sensor that senses black lines on the front of the robot body. ② Connect the sensor and the motor to the part that controls the motor according to the sensor's recognition. ③ Connect a battery to the robot and supply power.
	[Activity 3.] : Attaching a bulb that emits light ① Prepare a powerful light source. ② Fix the light source onto the robot.
	[Activity 4.] : Taking pictures of a light-emitting line tracer ① Move to a place where you can block out light, put a rough sketch on the floor where light will pass by, and fix it with tape. ② Place the line tracer robot on the path where light will pass by. ③ Install a tripod and fix a camera on it. ④ Start the line tracer and turn off the light. ⑤ Open the aperture as wide as possible, set the shutter speed to slow, and take pictures of the light-emitting line tracer. ⑥ Observe and record the principle of design elements from the pictures.

Table 4. Robot-Based Learning Activity Pictures

		
Making a path where light passes by	Making a robot which emits light along the path	Taking pictures of light

5. Study Method

5.1. Subject of Measurement

In this study, conducted in 2011, the subjects were 1,232 elementary school students, from first to sixth grade, registered at schools using robot-based learning. Table 5 provides detailed information.

Table 5. Measurement Subjects

Grades	Boys	Girls	Total Number of Participants
Lower (1^{st}, 2^{nd})	57	61	118
Middle (3^{rd}, 4^{th})	216	203	419
Upper (5^{th}, 6^{th})	360	335	695
Total	633	599	1232

5.2. Research Procedures and Method of Analysis

The analysis was performed over a period of seven months, from June through December 2011, and involved investigating the change in creativity before and after a robot-based class by conducting a survey. A creativity test [24] was conducted pre and post robot-based learning. The data was analyzed with the T-Test and post–verification was conducted using the SPSS 18.0 statistical program. Table 6 provides detailed information on the research procedure.

Table 6. Research Procedure

Number	Details		Time
1	Literature research		2011.6
2	Establishment of research projects (Researcher)		2011.7
3	Establishment of Robot-based instruction (Instructor)		2011.7~8
4	Execution of robot-based instruction		2011.9~12
5	Creativity test	Pre-	2011.8
		Post	2011.12
6	Result derivation and paper writing		2012.

5.3 Creativity Measurement Tool

The survey questionnaire used in this study was the elementary diagram creativity test (K-FCTES) [24], developed in Korea by benchmarking the Torrance Tests of Creative Thinking (TTCT) [23,26]. The K-FCTES was used in this study because the results of the TTCT, which consists of figure tests (TTCT-Figure A, B Types) and verbal tests (Verbal A, B Types), may not accurately measure creativity in the verbal test portion, due to cultural and linguistic variations between the United States and Korea; although the TTCT is used worldwide for creativity research.

In other words, this study employed the K-FCTES, a type of diagram test, to minimize scoring errors. The K-FCTES consists of chief diagram and stimulus diagram drawing tests. The former shows parts of 18 similar diagrams as lines, and requires the participant to complete the diagrams evoked by the parts. The latter shows parts of five diagrams like the Tai-chi pattern and points, and requires free completion with evoked forms. These tests measure fluency, originality, openness, and sensitivity [24]. Each test is five minutes long. Related information is observable in Table 7.

Table 7. Questions & Elements of Measurement

Category	Questions	Creativity Sub- factor	Inspection time
[Test 1] Draw chief figure	Provide some of the lines for the diagram and use them to complete the associated figure. Eighteen identical figures are presented.	Fluency, originality	5 minutes
[Test 2] Draw stimulus figure	Complete five given figures (part of the Tai-chi pattern, top pattern, ornament, 之's transform, points) freely.	Openness, Sensitivity	5 minutes

6. Results of Research

6.1. A difference in Creativity between Pre- and Post-inspection Score

The results of the investigation observing any changes in student creativity post robot-based learning are seen in Table 8 [4]. Table 8 shows that the difference in total creativity score between pre- and post-inspection was at the $p<.001$ level, and thus significant. Furthermore, all four of the sub-elements (fluency, originality, openness, and sensitivity) were at a $p<.01$ level, demonstrating higher significance in the post-inspection compared to the pre-inspection. Therefore, robot-based learning appears to effectively improve the creativity of elementary school students.

Table 8. Results of Change in Student Creativity

Category		N	Mean	Std.	df	t
Total Score	Pre-	1232	44.66	18.78	1231	-17.204***
	Post-		56.25	19.48		
Fluency	Pre-	1232	16.85	9.30	1231	- 20.415***
	Post-		22.98	9.34		
Originality	Pre-	1232	12.83	7.76	1231	- 14.845***
	Post-		16.79	7.88		
Openness	Pre-	1232	10.22	4.86	1231	-2.809**
	Post-		10.74	4.67		
Sensitivity	Pre-	1232	4.75	4.37	1231	- 5.813***
	Post-		5.73	4.43		

** p<.01, *** p<.001

6.2. A Difference In Creativity Between Pre- and Post-Inspection Score According To Gender

Examining gender differences in creativity before, during, and after tests produced the results seen in Table 9 [4]. Table 9 shows that elementary school boys and girls differed at a p<.001 level between the pre- and post-inspections, which is significant. Therefore, robot-based learning effectively improved the creativity of both male and female students.

Table 9. Results of Change in Student Creativity, According to Gender

Category		N	Mean	Std.	df	t
Boys	Pre-	633	43.03	18.12	63 2	-14.835***
	Post-		56.64	19.59		
Girls	Pre-	599	46.38	19.32	59 8	-9.615***
	Post-		55.83	19.37		

*** p<.001

6.3. Changes in Schoolboy Creativity, According to Grade Level

The result of the analysis of difference in the extent of creativity improvement in boys according to grade is seen in Table 10. Table 10 shows a significant difference (F=15.859, p<.001) in boys between grade levels (lower, middle, upper) after the robot-based class. In particular, compared to boys in the lower grades, middle and upper grade male students demonstrated higher creativity. After checking Scheffe's post inspection, significant differences were observed between the two groups, (the first group consisting of lower grades (1st and 2nd) and the second group consisting of middle (3rd and 4th) and upper grades (5th and 6th)), with the average difference between middle and upper grades being statistically insignificant.

Therefore, the lower grades appeared to be significantly different from the middle and upper grades for boys. That is, the creativity of schoolboys in the middle and upper grades distinctly improved in comparison with that of schoolboys in the lower grades.

Table 10. Results of Change in Schoolboy Creativity, According to Grade Level

Category		N	Mean	Std.	df	T	Scheffe's (Post-inspection)
Boys	Lower (1^{st}, 2^{nd})	57	43.42	20.00	2	15.859***	ⓐ<ⓒ*** ⓐ<ⓑ***
	Middle (3^{rd}, 4^{th})	216	56.56	20.38			
	Upper (5^{th}, 6^{th})	360	58.79	18.22			

ⓐ=Elementary (1^{st}, 2^{nd} grade), ⓑ=Elementary (3^{rd}, 4^{th} grade), ⓒ=Elementary (5^{th}, 6^{th} grade) ***p<.001

6.4. Changes in Schoolgirl Creativity, According to Grade Level

The result of the analysis of difference in the extent of creativity improvement in girls according to grade is seen in Table 11. Table 11 shows a significant difference (F=15.859, p<.001) in the creativity of girls between grade levels (lower, middle, upper) after the robot-based class. In particular, compared to the lower grades, the middle and upper grade levels demonstrated higher creativity in girls. After checking Scheffe's post inspection, significant differences between the two groups (the first group consisting of the lower grades (1st and 2nd), and the second group consisting of the middle (3rd and 4th) and upper grades (5th and 6th)) were observed, with the average difference between middle and upper grades being statistically insignificant.

Therefore, the lower grades appeared to be significantly different from the middle and upper grades for girls. That is, the creativity of schoolgirls in the middle and upper grades distinctly improved in comparison with that of schoolgirls in the lower grades.

Table 11. Results of Change in Schoolgirl Creativity, According ro Grade Level

Category		N	Mean	Std.	df	t	Scheffe's (Post-inspection)
Girls	Lower (1^{st}, 2^{nd})	61	42.39	16.55	2	18.201 ***	ⓐ<ⓒ*** ⓐ<ⓑ***
	Middle (3^{rd}, 4^{th})	203	55.95	19.18			
	Upper (5^{th}, 6^{th})	335	58.21	19.02			

ⓐ=Elementary (1^{st}, 2^{nd} grade), ⓑ=Elementary (3^{rd}, 4^{th} grade), ⓒ=Elementary (5^{th}, 6^{th} grade) ***p<.001

7. Conclusions

This study examines the influence of robot-based learning on elementary school student creativity. For this purpose, we conducted robot-based learning on general courses, such mathematics, social studies, science and art. Moreover, a creativity test was conducted twice, both pre and post robot-based learning. The results and conclusions of this study are as follows:

First, robot-based classes were found to increase creativity in an effective way, and all the sub-elements of creativity (fluency, originality, openness, susceptibility) had significantly higher scores in the post-verification than in the pre-verification stage. Such results indicate that robot-based education is an effective method to develop creativity across all grades in elementary school.

Second, the creativity of male and female students improved significantly after robot-based learning. That is, robot-based learning effectively improved creativity regardless of gender. Such results imply that robot-based education is a useful method for arousing interest in technology.

Lastly, in comparison with lower grade students, both male and female middle and upper grade students showed distinct improvement post robot-based learning. With respect to these results, in order to benefit from robot based learning, it is suggested that age and development levels be considered when incorporating this tool into the general curriculum. In order for robot-based classes to contribute towards increasing student creativity, a systematic class strategy to effectively utilize the robot medium according to student level is required.

The results of this research into the potential to use robots in education and the effect of robot-based learning on elementary student creativity in regular education courses are significant.

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