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Learning Effects of Pedagogical Robots with Programming in Elementary School Environments in Korea

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Abstract

The purpose of this study was to develop systematic and effective robot-based learning with programming to improve learner's creativity and understand class satisfaction at the elementary school level. In the study, an instructional strategy was developed to help learners express learning contents including Korean, mathematics, and music in the movement of the educational robot. The robot was developed by a telecommunication company in Korea and Scratch-type programming was adopted for the learners to program the robot. A total of 27 third-grade students at an elementary school in Korea participated in the treatment for 12 weeks. In the results, two sub categories of creativity were found to be significantly improved and the class satisfaction was relatively high. Suggestions were made based on the results.

Keywords: Class Satisfaction, Creativity, Elementary School, Pedagogical Robot, Programming

1. Introduction

Programming and coding education receives much attention as one of the new curriculum trends. In September 2014, the British government began a new computing subject including coding lessons for children as young as five[1]. In the U.S., coding education programs are continuously expanding as the IT job market flourishes[2].

Also, Belgium, the Czech Republic, Estonia, Finland, and Hungary have started to invest in information technology education[3]. Through programming education, learners can enhance their cognitive abilities such as creativity and logical thinking. However, the established programming education has limitations since it is difficult for students to learn programming languages. Accordingly, learning focuses on acquiring programming languages, resulting in little chance to practice creative learning activities.

On the other hand, Scratch, developed by MIT Media Lab in 2006, helps learners understand the principles of programming by dragging and dropping block-style icons. With Scratch, learners can program their own interactive stories, games and animations and share their creations with others in the online community[4].

In Korea, the government has announced that it would boost software learning at the elementary and secondary levels of education with the new trends of using programming languages for learning[5].

Meanwhile, there is also a growing interest in using robots for educational purposes. At the initial stage of working with educational robots, learners used to design or assemble the robots. Now, they are expected to manipulate functional robots to enhance their learning abilities. Moreover, educational programming as a medium for communicating with robots can be an alternative for learners to acquire knowledge and progress in their cognitive learning.

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Both educational robots and educational programming can offer learners authentic experiences. This study focused on learner's using robots with educational programing language to investigate changes in creativity and class satisfaction in Korean elementary school settings. The research questions are as follows: 1. Does programming education with robots enhance learner's creativity? 2. Are students satisfied with programming education with robots?

2. Theoretical Backgrounds

2.1 Programming Education and Scratch

It has been difficult to estimate the effectiveness of learning by or with programming even though research has emphasized the importance of programming education. Some of the reasons might be the focus of programming learning on drill and practice with cramming[6]. This has been a somewhat inevitable limitation because programming languages themselves are difficult to learn. Memorizing the commands of a programming language results in low motivation and a negative attitude toward programming[7].

However, Educational Programming Language (EPL) is considered to make up for the weak points of other programming languages. Students can easily use EPL to express their thoughts and intentions. For example, Scratch, one of the EPLs developed by MIT Media Lab, uses drag and drop style commands as well as helps learners command with ease[8]. Scratch has an intuitive user interface with various images and sounds. It also supports multiple languages including Korean[9].

2.2 Robot Education

Educational robots refer to robots for enhancing learner's abilities in problem solving, collaboration, logical thinking, and computer programming[10]. Using robots in education helps learners bring unique and fresh ideas and use their imaginations so that learners continue thinking. Song J[11] defined educational robots as robots for learning algorithms through programming. Some pedagogical robots serve as learning materials, while others act as teachers. With robots as learning materials, learners directly operate the robots for learning. Meanwhile, robots as teachers offer educational content.

There has been a wide range of research on learning using robots: instructional design and development using robots[12,13], robots as educational tools[14–17], robot designs for educational purposes[18–20], thinking ability development through robots[21,22], and computer science learning using robotics[23].

Moreover, as the need for programming education increases, educational robots receive attention as well. This is because using robots in programming education reduces cognitive loads and helps students acquire high-order thinking abilities. Programming learning with robots also offers authentic and physical environments for reflective thinking, which change abstract concepts into concrete and experimental experiences[23,24].

2.3 Creativity

Creativity stems from the Latin word "creatio" which means "to make." Creativity is a process of transforming knowledge using divergent production[25]. Divergent thinking enables creative thinking which consists of sensitivity to problems, fluency of thinking, flexibility of thinking, originality of thinking, elaboration of thinking, and a factor involving reorganization or redefinition.

Torrance EP[26] regarded creativity as thinking with unique ideas, different views, and new ways of thinking. Factors of creativity include cognitive elements such as fluency, accuracy, uniqueness, and abstractness. Courage, curiosity, spontaneity, flow, and an adventurous spirit are some of the affective elements of creativity. Urban KK[27] offered elements and models of creativity based on the relationships between learner characteristics and learning environments: Creativity includes personality (pertinacity for tasks, concentration, motivation, openness, and persistency) and cognitive factor (divergence thinking ability, acting ability, and general and specific knowledge). All of these elements are considered to be inter-related to enhance creativity.

As previous research found that programming education helps enhance learner's creativity, this study aimed to investigate how robots with programming education affect on creativity among elementary school students in Korea. The student's class satisfaction was measured as well.

3. Methodology

3.1 Participants

The study participants attended "A" elementary school located in Seoul, Korea. The school ran four different creative experiential activities. One activity was robot education with programming. A total of 26 students from four classes voluntarily participated in the research program. The robot class met for two hours per week for 12 weeks.

3.2 Research Design

To examine the research question, the effectiveness of the treatment were investigated. Methodologically, a paired t-test was conducted with pre-test and post-test results for creativity measurement.

O_1	X	O_2

O_1: pre-test (creativity)
X : programming education with robots
O_2: post-test (creativity, class satisfaction)

3.3 Research Instruments

3.3.1 Educational Robot

An educational robot that was developed by a telecommunication company in Korea was used for the study (Figure 1). The robot has a speaker, a recorder, and multiple touch and proximity sensors. Also, Light Emitting Diode (LED) lights and Object Identifier (OID) sensors respond to users. Movement motors installed inside the legs and waist can make the robot move in any direction. Using the robot with Bluetooth and smartphones enables it to perform additional functions.

Figure 1. Educational robot for research.

3.3.2 Programming Language

Scratch-type programming was used for the research, which allowed learners to easily learn and use the robot (Figure 2). Learners were to enter commands into laptops and to make the robot move. The commands consisted of events with visual active objects. One-to one computing environments were supported for the participants to use the robot with programming.

Figure 2. Sample commands in the programming language.

3.3.3 Curriculum

The curriculum in the study was divided into three stages: the fundamental, advanced and application stages. The details of the stages are presented in the Table 1.

Table 1. Curriculum for the research

Stage	Activities	Period
Fundamental	To learn and practice basic programming language.	1-3rd weeks
Advanced	To learn and practice advanced programming language.	4-6st weeks
Application	To apply programming to Korean, music and mathematics subjects activities.	7-10th weeks

In the fundamental stage, the participants learned basic programming commands to move the robot. Next, in the advanced stage, they learned the advanced level commands and how to combine commands to make the robots perform multiple tasks. In the last stage, they applied programming to activities in Korean, music, and mathematics subjects. Table 2 shows the activity designs.

Table 2. Instructional design of the application stage

Subject	Content	Period	Activities
Korean	Commu-nication	1 week	- two students make one group. - moving robots imitating speech.
Mathe-matics	Division	2 weeks	- two students make one group. - moving robots on monopoly using the four rules of arithmetic.
Music	Stars and Dreams	1 week	- two students make one group. - moving robots according to a music.

3.4 Measurement Instrument

The Korean Figural Creativity Test for Elementary school Students (K-FCTES)[28] was adopted to measure the participant's creativity. The K-FCTES question items include traditional Korean designs and patterns reflecting emotions and feelings of Koreans. The instrument estimates sub-spans of creativity including fluency, originality, sensitivity and openness. The instrument has been renowned and widely used with high reliability in Korea. In this study, the test was administered twice, as a pre-test and post-test respectively.

Class satisfaction was measured with 10 items: "The class had a good academic atmosphere," "I understood the instruction well," "The class was interesting," "I concentrated on the instruction," "I actively participated in the class," "The instructor used various learning materials," "The instructor taught me considering my level," "The class was rewarding," I learned a lot from the class," and "I would recommend this class to other students."

4. Results

4.1 Creativity

In the pre-test, the means of fluency, originality, sensitivity, and openness were 45.33, 50.10, 52.46, and 51.64, respectively. In the post-test, the means were 50.97, 54.86, 48.46, and 51.22. Fluency significantly improved at the level of .01. Also, the difference in originality was significant at the level of .05. Therefore, the programming instruction using robots helped the students increase their fluency and originality. Table 3 below presents the results.

Table 3. Pre-Post test results for creativity

Variable		M	SD	T	P
Fluency	pre	45.33	7.22	-3.13	.004**
	post	50.97	9.03		
Originality	pre	50.10	8.03	-2.35	.027*
	post	54.86	10.60		
Sensitivity	pre	52.46	11.93	1.68	.104
	post	48.46	8.60		
Openness	pre	51.64	10.19	019	.847
	post	51.22	12.23		

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

4.2 Class Satisfaction

After the treatment was over, the class satisfaction questionnaire was distributed to the participants. The items were rated on a five-point Likert scale. The results showed that the mean was 4.45 and the standard deviation was .52. Class satisfaction was measured by descriptive statistics, and it was found that almost all of the participants were very satisfied with the programming education with robots.

5. Conclusion and Suggestions Results

This study examined the effects of programming education with robots on learner's creativity and class satisfaction. A total of 27 elementary school students participated in a 10-week experiment with designed activities. The creativity and class satisfaction test results are discussed below.

First, the results from the pre-post paired t-test analysis to understand the differences in the creativity revealed that fluency (p = .004) and originality (p = .027) were significantly improved. Second, class satisfaction was measured by descriptive statistics and the mean was 4.45 out of 5.

Since the dataset used in the analyses was from a small participant sample, the generalization of the results has some limits. Nevertheless, this study had a unique strength in that both programming education and robots were jointly designed to improve the effectiveness of learning. Based on these findings, the following suggestions are made.

First, regarding creativity, investigation is needed into what factors and contexts enhance elements of creativity in the study of programming education and robots. Only two domains were effective in this research. Second, other than creativity and class satisfaction, further variables should be considered in programming education with robots. For example, computational thinking, logical thinking, and academic performance are considered important variables in this area. Third, systematic learning strategies should be developed in programming education with robots. In the study, specific learning designs were made in the three subjects (Korean, mathematics, and music). It is necessary to carry out further research on which subjects and curricula the learning settings are effective for and to develop optimal instructional strategies for them.

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