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The Effect of Robot Programming Education by Pico Cricket on Creative Problem-Solving Skills

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Abstract: A substantial programming support tool that integrates a physical object such as a robot and educational programming language is one of useful instruments to foster not only general problem-solving skills but creative thinking. That provides an actual opportunity for learners to simulate the problem-solving process designed by themselves by utilizing the physical object to modify any incorrect prior knowledge or stereotype of problem-solving process that they may have. Such an experience is especially effective at stirring up creative thinking that refers to steadily exploring new solutions and seeking after a positive change of the given environ- ments. The purpose of this study was to develop a robot-aided programming program of instruction, and robot programming education by the program turned out to exercise a significant influence on the creative problem-solving skills of the learners who received that education. Specifically, that had a good effect on their divergent thinking faculty, critical/logical thinking faculty and motivational elements, which were subfactors of creative problem-solving skills. Therefore the robot programming education could be said to be one of good ways to improve the creative problem-solving skills of learners.

Keywords: Robot Programming, Pico Cricket, Creative Problem-Solving Skill

Introduction

Creative problem-solving skills are mandatory for everybody in the 21st century's information and knowledge-based society. Problem-solving skills are especially required to find the best solution in the given circumstances, and creativity is to explore new possible solutions to pursue better environments. Exploring ways of fostering both of problem-solving skills and creativity at the same time is very worth doing, as the object of modern education is to nurture competent people in response to the needs of modern society. Algorism and programming education can be defined as the best education for the improvement of problem-solving skills. A programming process that one designs a significant algorism to find the best solution in the given problem situation and implements it on the computer makes it possible for him or her to gain substantial experience about the specific abstract concept.

However, algorism and programming education geared toward fostering problem-solving skills calls for abstract thinking and might eventually put pressure on beginning learners who are exposed to programming education for the first time or on young learners who don't yet make a full cognitive development. Furthermore, the process of acquiring programming language and its grammar is likely to impose another cognitive load on them. In the past, programming education just focused on the use of particular programming language or grammar rather than the process of designing and developing algorism that is the actual process of problem solving[7].

In recent days, studies have concentrated on the utilization of educational programming languages such as LOGO, Squeak Etoys, Alice and Scratch in order to solve the problem with programming learning.
Therefore this study attempted to design instructional strategies required for robot-aided programming education for the improvement of creative problem-solving skills and to analyze the impact of the strategies on the problem-solving skills of learners.

1. Background

1.1 Pico Cricket

Pick Cricket is an educational programming kit that is based on Papert's constructivist educational philosophy and was produced in 2006 jointly by the MIT Media Lab's research team, Lego and Playful Invention Company. As that involves programmable bricks, learners are able to configure their works by utilizing the major sensors of the robot and to prepare various programs geared toward stirring up the motion, sensing, interaction and communication of the works.

1.2 Creative Problem-Solving Skills

Creative problem-solving skills refer to every kind of process that an individual or a group thinks creatively to solve a certain problem or to such efforts. There are a wide variety of factors in problem solving, which interact with one another in a complex and dynamic manner, and the skills are defined as an ability to be useful for problem solving and produce a unique output or solution[7]. Initially, studies of creative problem-solving skills mostly centered around the cognitive thinking process of individuals. Lately, however, a lot of studies have focused on what kind of environmental conditions or motivations are effective at stimulating the display of problem-solving skills or on the interaction between the skills and personality. In other words, it's believed that one can exert his or her creative problem-solving skills through the interaction among diverse components involving his or her background knowledge, cognitive ability, motivation, personality traits and related environments[4]. It denotes that the development and improvement of creative problem-solving skills are possible by employing successful strategies of instruction or by creating appropriate learning environments. In particular, recent studies of the relationship among creativity, knowledge and problem-solving skills have increasingly emphasized the importance of individuals' domain knowledge and problem-solving skills as a means to foster creative problem-solving skills[6]. The findings of the studies show that not only the domain knowledge of individuals but their procedural knowledge like general problem-solving skills and intrinsic motivation are all vital for the improvement of creative problem-solving skills.

1.3 Robot-Aided Programming Learning

The Pico Cricket project is an extended form of such robot-aided projects. That enables learners to make more extensive and creative works(e.g. flower, insect, portable lantern or musical instrument) by utilizing various types of materials(e.g. textile, paper, plastic, metal craft item or glass beads) that are more diverse than those of the LEGO bricks. And that provides programming environments for them to get their works in control, and enables them to design and program artistic works by integrating light, sound, music and motion. The Pico Cricket takes full advantage of the benefit of existing robot-aided education and aims to ignite the interest of learners in diverse ways. Namely, existing robot-aided education merely focuses on the performance of challenges by triggering the competition of learners as if they played robot games. That results in failing to spark the interest of learners or satisfy their needs, and the Pico Cricket can be called an attempt to make up for the shortcoming of existing robot-aided education[5].

2. Instructional Design for Robot-Aided Programming Learning

A program of instruction for robot-aided programming was developed in accordance with the following design principles to step up the development of creative problem-solving skills:

First, a variety of open-ended, activity-theme-centered learning activities were prepared instead of simply sticking to existing challenge-oriented practices. Learners select activity themes that they are going to deal with by using the robot, share mutual ideas about the same interested fields and engage in programming. This process provides an opportunity for them to solve the given problem, to do problem finding in real life and to perform problem representation activities.

Second, 'cooperative activity tasks' were conceived to provide intrinsic motivation to learners, and the use of competitive activity tasks was avoided. Lately, researchers of creativity view intrinsic task motivation as indispensable to the display of creativity[3]. According to Csikszentmihalyi's system model[1] of creativity, an individual cannot be called a creative person if his or her creative output doesn't get recognized by others and society.

Third, the substantial programming tasks prepared to bolster creative problem-solving skills are ill-structured and aim at modelling of various problems in real life, which might put excessive cognitive strain on beginning learners. Particularly, they should learn how to configure and manipulate physical objects and how to use the programming tool to program the physical objects, and that is likely to make them put less time and effort into creative problem-solving process itself. In this study, several instructional strategies were devised to lower excessive cognitive burden and extrinsic cognitive load that may be imposed on learners. When the instructional strategies were designed, the 4CID(components instructional design) model was utilized, which is an instructional design method to back up complicated problem-solving process in real life.

3. Method

3.1 Hypothesis

The following hypotheses were formulated:

(1) Robot programming education by the Pico Cricket might affect creative problem-solving skills.

(2) Robot programming education by the Pico Cricket might affect four subfactors of creative problem-solving skills.

3.2 Subject

The subjects in this study were 40 students who were in their sixth grade in an elementary school located in North Choongchung Province, South Korea.

3.3 Instrumentation

3.3.1 Creative Problem-Solving Inventory

The instrument used in this study to assess creative problem-solving skills is the MI Research Team's creative problem-solving skills inventory at the Psychology Research Center of Seoul National University, which was based on the Korea Educational Development Institute's study of the development of creative problem-solving skills inventory. This instrument covered four different domains with five items each, and consisted of 20 items in total. Each item employed a five-point scale.

Domains to be tested	No. of item
Specific domain(understanding of knowledge, thinking function, understanding and mastery of technology)	5
Divergent thinking faculty	5
Critical, logical thinking faculty	5
motivational elements	5

3.3.2 Robot-Learning Program for the Improvement of Creative Problem- Solving Skills

The robot-learning program used in this study to bolster creative problem-solving skills was devised by combining typical materials and a programming robot, which is a new digital technology, to inspire students to integrate arts, science, music and engineering for the purposes of creation, invention and exploration. The preliminary validity of the program was verified by a programming expert group, and then a pilot test was conducted to analyze its reliability. As a result, the Cronbach alpha coefficient of the program was .732, and that was utilized in this study since it turned out to be appropriate for judging creative problem-solving skills.

Period	Learning theme	Learning content	Things to be prepared	Programming-related domain
1-2	Art car	Make a car that moves when one pushes the button and changes direction when one claps his or her hands.	the Pico Cricket, Lego block, Styrofoam, colored paper, paints	Conditional statement, for statement, variables
3-4	Birthday cake	Make a cake that gets the candles to light up and snuff out repeatedly and emits a song to celebrate birthday when one claps his or her hands.	the Pico Cricket, thick paper, colored paper	Conditional statement, for statement, variable
5-6	Compass	Make a compass that moves at a particular angle according to the frequency of clapping.	the Pico Cricket, Lego block	Conditional statement, for statement, variable
7-8	Painter	Make a printer robot.	the Pico Cricket, Lego block, paints, paper cup	Conditional statement, for statement, variable
9-10	Smart car	Make a car that is driven according to the frequency of clapping. One time of clapping: turn left, Twice of clapping: turn right Three times of clapping: go straight ahead Four times of clapping: stop	Two sets of Pico Cricket, Lego block	Conditional statement, for statement, variable
11-12	Walking robot	Make a walking robot	the Pico Cricket, Lego block	Conditional statement, for statement, variable
13-14	Dancer	Make a dancer who turns around in a different direction when one claps his or her hands	the Pico Cricket, Lego block, doll	Conditional statement, for statement, variable

3.4 Research Design and Process

The research design and process of the study are as follows:

Group	Pretest	Experiment	Posttest
An experimental group	O1	X1	O2

The experimental group took a test in creative problem-solving skills before the experiment was conducted. After the experiment, the same test was carried out again to see whether there would be any differences between their pretest and posttest scores. In other words, a paired-samples t-test was conducted twice, and the experiment was implemented in 14 sessions.

4. Result

4.1 Creative Problem-Solving Skills

The paired-samples t-test was carried out two times to determine the impact of the robot programming education by the Pico Cricket on creative problem-solving skills. Before that education was provided, they got a mean of 3.07, and then 3.39 after that. According to the results of the paired-samples t-tests, the gap between their two scores was statistically significant at the .01 level of significance. It indicated that the robot programming education by the Pico Cricket was effective at improving creative problem-solving skills.

p<.01

Group	Collective averages	Standard deviation	t	p
Pretest	3.07	.41	=3.553	.001
Posttest	3.39	.36		

4.2 *Specific Domain(Knowledge, Thinking Function, Understanding and Mastery of Technology)*

The first subfactor of creative problem-solving skills is skills of specific domain(knowledge, thinking function and understanding and mastery of technology). According to the results of the paired-samples t-tests, they got a mean of 3.07 before the robot programming education, and 3.20 after that. But the gap between the two was not statistically significant.

p<.001

Group	Collective averages	Standard deviation	t	p
Pretest	3.07	.46	-1.207	.235
Posttest	3.20	.47		

4.3 *Divergent Thinking Faculty*

The second subfactor for creative problem-solving skills is divergent thinking faculty that is an ability to conceive something unknown or new things. According to the results of the paired-samples t-tests, they got a mean of 2.94 before the robot programming education and 3.14 after that. The gap between the two was statistically significant at the .001 level of significance. Therefore it could be said that the robot programming education by the Pico Cricket was effective at bolstering divergent thinking faculty.

p<.001

Group	Collective averages	Standard deviation	t	p
Pretest	2.94	.57	-1.493	.000
Posttest	3.14	.68		

4.4 *Critical/Logical Thinking Faculty*

The third subfactor of creative problem-solving skills is critical/logical thinking faculty that is an ability to discriminate between right and wrong. According to the results of the paired-samples t-tests, they got a mean of 3.13 before the robot programming education and 3.81 after that. The gap between the two was statistically significant at the .001 level of significance, and it implied that the robot programming education by the Pico Cricket was effective at boosting critical/logical thinking faculty.

p<.01

Group	Collective averages	Standard deviation	t	p
Pretest	3.13	.66	-1.493	.000
Posttest	3.81	.53		

4.5 *Motivational Elements*

The fourth subfactor of creative problem-solving skills is motivational elements. It refers to whether there is what makes something happen or not, and involves target setting, inquiry needs, interest and efforts for the attainment of selected objects. According to the results of the paired-samples t-test, they got a mean of 3.12 before the robot programming education and 3.39 after that. The gap was statistically significant at the .05 level of significance, and it could be said that the robot programming education by the Pico Cricket was effective at strengthening the motivational elements.

$p<.01$

Group	Collective averages	Standard deviation	t	p
Pretest	3.12	.43	-2.084	.044
Posttest	3.39	.58		

5. Conclusion

The substantial programming support tool that integrates a physical object like a robot and educational programming language is a useful means to not only foster problem-solving skills but further creative thinking. That enables learners to gain substantial experience in simulating the problem-solving process designed by themselves by utilizing the physical object, and thereby provides a chance for them to correct any incorrect prior knowledge or stereotype of problem-solving process that they may have. This experience is effective at stirring up their creative thinking faculty, which refers to steadily exploring new solutions and seeking after a positive change of the given environments. But the utilization of the educational programming language and physical object such as the robot might impose another cognitive load on learners, and the use of new media or state-of-the-art technology as a means of motivation might end up producing just temporary effects.

The purpose of this study was, therefore, to design instructional strategies for robot-aided programming learning geared toward improving creative problem-solving skills and to examine the impact of the strategies on the creative problem-solving skills of learners.

The robot programming education by the Pico Cricket could be said to have a significant effect on the problem-solving skills of the group that received that education. Besides, that education was evidently effective at boosting their divergent thinking faculty, critical/logical thinking faculty and motivational elements, which were the subfactors of problem-solving skills. The findings of the study suggested that the instructional strategies for the robot programming learning exerted a significant influence on not only problem-solving skills, which denoted general procedural knowledge, but all the affective elements involving motivation.

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