Engineering to See and Move: Teaching Computer Programming with Flowcharts vs. LEGO Robots

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Abstract—**This study investigated the effect of integrating LEGO Robots into an elementary school programming class through examining the learning achievement and teacher-student interaction. A self-developed course was used to present the instructional project, and the research subjects were 80 fifth and sixth grade students in two elementary schools. Before the instruction of the course, the researchers divided students into the experimental group and the control group respectively for giving programming instructions based on "integration of Lego Robot" and "traditional illustration of flowcharts" for three weeks. The results showed that the fifth and sixth grade students who received programming instructions based on integration of LEGO Robots performed higher learning achievement in programming ability than those who received instructions based on illustration of flowcharts. In addition, integration of LEGO Robots into programming instructions had a significant effect on teacher-student interactions and teacher-student interactions became more student-centered.**

Index Terms—**Computer programming, LEGO Robot, Logo, Teacher-student interaction**

I. INTRODUCTION

Many cognitive researchers take the 'learning' as 'a process of model building'. When students first come to know some new skills or knowledge, they will form a model in minds. After spending a great deal of time practicing, playing, shaping, restructuring the model, they gradually develop better understanding about the system of the knowledge [1]. Therefore, a project of artifact construction can help them to become effective learners. 'Microworld', a term first used by Papert, is such a learning environment for learners to build their own models [2]. Students learned in a microworld to think in an assumption-verification perspective. The process provided the learners with opportunities of knowledge integration, problem solving and cognitive development [3].

Although there are sound educational and political perspectives to indicate a firm basis for group work being an important component of learning science or technologies, there is still some skepticism as to whether the theoretical advantages are borne out in practice [4, 5]. This study, combining modeling and collaborative learning, addresses these issues through qualitative analysis of a case study. With experimental research design of traditional instruction and integrating LEGO Robots with computer programming instruction, the researcher investigated the effect of LEGO Robots mediated learning in an elementary school programming class through examining the learning achievement and teacher-student interaction. Tests on programming learning achievement were conducted before and after the programming instructions. In addition, classroom observation was conducted to collect data on interactions.

II. LITERATURE REVIEW

A. Computer Programming Instruction

The learning difficulties that novice programmers face are the abstract concept. As the programs become more complicated, most learners become less motivated to learn [2]. One of the problems is teachers emphasized much on syntactic knowledge rather than semantic knowledge that the joys and funs of computer programming were gradually replaced by frustration. To resolve the problems, many prior studies combined modeling artifacts such as LEGO Robot with programming instruction to enhance learners' motivation and instruction effectiveness [6-10].

B. Interaction in Classrooms

Group learning has been identified as an effective strategy. Based on the framework of social constructivism, a number of designs such as cognitive mentorship, scaffolding, and community of practices will empirically verified to provide students opportunities to develop communication skills, social skills, meta-cognitive skills, or critical thinking [11-17].

The core of successful group learning is interaction between group members. In classrooms, how to cultivate an environment encouraging interaction between teacher-pupil and between peers is an important issue for improve learning.

III. RESEARCH METHODS

A. Research Procedure

A self-developed course was used to present the instructional project, and the research subjects were 80 fifth and sixth grade students in two elementary schools. Before the instruction of the course, the researchers divided students into the experimental group and the control group respectively for giving programming instructions based on "integration of LEGO Robot" and "traditional illustration of flowcharts" for three weeks. As Table 1 shows, students then learned to program in Logo language during the next seven weeks. Students were given a pretest on programming learning achievement before receiving the basic Logo Turtle programming instructions. At the end of seven weeks, a posttest was conducted after the instructions were completed.

TABLE I.
RESEARCH PROCEDURE

Period	Experiment Group	Control Group
Week 1 to Week 3	LEGO Robots	Flow-charts
Week 4 to Week 10	Logo Programming	

B. *Tasks*

For the experiment group, LEGO computerized bricks and the visual software (see Fig. 1) to form a microworld in which the students could learn through interaction with the emerging artifacts. Students used the LEGO bricks to design and build an artifact, and then implemented the designed functions by controlling the computerized bricks with programs.

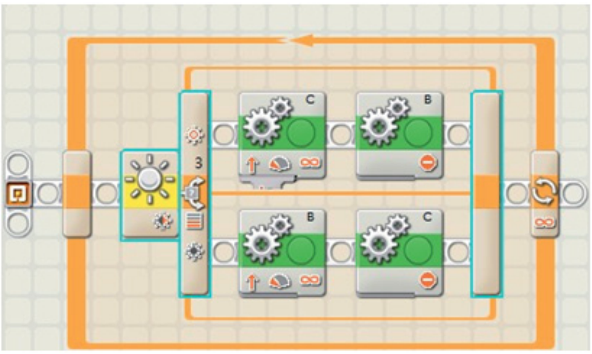

Figure 1. Visual software to control the LEGO robot

The students learned in a microworld to think in an assumption-verification perspective. The process provided the learners with opportunities of knowledge integration, problem solving and cognitive development. As in Fig. 2, students build an artifact with LEGO bricks and then use visual program software to control it. For the control group, teachers introduced flowcharts to students and showed the structure of programs and practiced logic thinking.

Figure 2. Students build and control an artifact with programs

C. *Data Collection*

During the project, students planned a series of stages toward their goal and monitored their progress. Meanwhile, the researcher collected and analyzed the data, which consisted of programming tests, observation, logs of work, and interviews. During the instructions, a video recorder was used to record the interactive models between teachers and students for subsequent research and observation. Finally, a posttest was conducted after the instructions were completed. One-way ANOVA, chi-square test, and other statistical analysis methods were completed. One-way ANOVA, chi-square test, and other statistical analysis methods were applied to obtain the research results. Data derived from interviews, video recordings, and related documents were also used to verify and discuss the empirical results.

In this study, three kinds of instruments were used to analyze the experiment data:

1. Achievement test: A test on the instructed concepts of Logo programming developed by researchers. The value of Cronbach's α is 0.497 for pretest and 0.617 for posttest, which indicated a good consistency. The item difficulty index is between 0.2 and 0.8, stands for appropriate difficulty.

2. Attitude questionnaire: A Likert-style attitude questionnaire on LEGO learning.

3. FIAC: A pupil-teacher interaction observation system based on Flander's theory of language interaction [17]. As in Fig. 3, a web-based software was used to collect and analyze data. The website can be accessed through http://diss.tjps.tp.edu.tw/main.htm.

Figure 3. A screen shot of in-classroom activities analysis.

IV. RESULTS

A. *Logo Programming Skill*

Students who received programming instructions based on integration of LEGO Robot performed significantly better than those who received instructions based on illustration of flowcharts. In Table 2, the performance of two groups showed no difference in pretest, but significantly different in posttest.

Students of the experiment group tried to control robots through the cycle of hypothesis and verification in the LEGO Robots lessons. They were accustomed to failure and revision. In addition, the novelty of robot control maintained their high motivation. These experiences resulted in positive influences on their subsequent lessons of learning programming.

In contrast, traditional instruction with flow-chars aimed to skip the complex details of language syntax and concentrate on the attainment of semantic knowledge of problem solving. However, the abstract concept and teacher-dominant instruction kept students from appreciation of programming.

TABLE II.
T-TEST OF LOGO PROGRAMMING TESTS

	Pre-test			Post-test		
	Average	SD	t	Average	SD	t
Experiment group	9.15	9.77	.137	59.70	22.46	.002*
Control group	11.75	4.97		47.05	4.82	

*P<.05

B. Interaction

The result showed that the experiment-group students performed much better in actively initiated conversation. A chi-test confirmed a statistical significance (x^2 =1752.849，p=.000<.05). The teacher also used less direct commands during instruction for the experiment group. In other words, it indicated that the instruction integrating LEGO Robot would help to cultivate a more constructive learning environment (see Table 3).

TABLE III.
THE INTERACTION COMPARISON

Item	Experiment Group	Control Group
teacher talk	64.49%	73.13%
pupil talk	21.96%	8.74%
silence or confusion	13.55%	18.13%
indirect-to-direct ratio	199.12%	209.67%
teacher response ratio	66.57%	67.71%
teacher question ratio	15.19%	11.36%
pupil initiation ratio	34.67%	21.99%

C. Attitude

As in Table 4, most students of experiment group expressed positive attitude toward the educational functions of LEGO Robot in learning programming.

TABLE IV.
ATTITUDE OF EXPERIMENT GROUP TOWARD LEGO ROBOT

Item	Strongly agree	agree	neutral	disagree	strongly disagree
LEGO Robot helps to understand programming	25%	45%	21%	7%	2%
Controlling LEGO Robot helps to debug programs	19%	40%	24%	12%	5%
LEGO Robot visual programs help me to revise my program	17%	52%	24%	7%	0%

As table 5 shows, most students considered LEGO Robots helpful in understanding programming and revising programs. Following are comments by students in the interviews:

- The LEGO Robot lessons provided us with hands-on experiences. Listening to lectures is different from experimenting.
- In LEGO Robot activities, I became bold to try and experiment. Nobody would be scolded for doing experiments unsuccessfully. Whenever I succeeded, my peers would cheer out and ask me how to achieve it. It was encouraging.
- Although the programming syntax of LEGO Robot is quite different from Logo, I can assimilate the concept of 'loop'.

TABLE V
HOW LEGO ROBOTS HELP TO LEARN PROGRAMMING

Item	Strongly agree	agree	neutral	disagree	strongly disagree
LEGO Robot helps to understand programming	25%	45%	21%	7%	2%
Controlling LEGO Robot helps to debug programs	19%	40%	24%	12%	5%
LEGO Robot visual programs help me to revise my program	17%	52%	24%	7%	0%

V. CONCLUSION

This study indicated that LEGO Robot mediated learning by providing project-based, hands-on experiences to learning programming. The different instruction resulted in differences in motivation and controlling concept on programming. Students reflectively think of their engagement in building and controlling Robots. And the experience continued through the duration of Logo programming learning. The process revealed several differences: First, The project helped the students to practice their own talents and creativities to build up robots with LEGO bricks. Therefore, students were given opportunities to explore themselves in joyful ways.

Secondly, the Robot experiences helped students to recognize the importance of active learning. Building up team spirits for group work would be a big step toward task accomplishment. Meanwhile, they appreciated the style of self-directed learning in classroom. And they were willing to initiate conversation and thus would acquire better interpersonal skills.

This study developed instruction plan and environment for beginning learners based on a synthesized process of problem solving with LEGO Robots and flow-charts, adapted to the particular requirements of programming tasks, and the interactivity at each stage. From this study, it is hoped that information technology, and its impacts on computer science education, will bring additional insights to the effective and innovative approaches of computer programming instruction. There continues to be a need to research on computer programming instruction taking into consideration the difficulties involved in learning programming and the existing environments and their shortcomings with respect to how well the instruction meet students' needs. A further implication for future research includes developing a longer and more sophisticated research design and the critically-evaluated measurements to understand its influences.

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