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The effects of constructing robot-based storytelling system on college students' computational thinking skill and technology comprehension

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Abstract— Recent college students have been observed to be motivated and engaged in acquiring information and communication technology (ICT) knowledge and skills with robots and digital media. The purpose of this study is to develop students' technology comprehension through a learning activity by constructing robot-based storytelling systems. A sample of 15 college students participated in the program. Data collected include the pre-and post- computational thinking tests (CT) and computational thinking skill (CTS) tests for evaluating their learning effects of technology comprehension (TC) in terms of computational thinking knowledge and skills and their perceptions toward the robot-based storytelling development environment and learning activities. The results show that the learning activities were an effective approach for enhancing the students' TC as shown in the post-test. The differences between the students' CT and perceptions were also confirmed. The results revealed that the learning activities with the robot-based storytelling development environment could improve the students' TC knowledge and skills, and learning perceptions.

Keywords—Technology comprehension; Computational thinking; Robot-based storytelling; Information and communication technology

I. INTRODUCTION

The emergence of the internet of things (IoT), artificial intelligence (AI), and robotics already contribute significantly to market growth [1, 2]. In particular, the knowledge and skills of information and communication technology (ICT) play an important role in developing students' abilities in problem-solving, computational thinking (CT), and creativity [3].

As the design of human-robot interaction (HRI) performs a critical interface in supporting the communications and interactions between humans and robots [4]. The HRI related studies have drawn much attention by researchers, especially in robot-based storytelling (RST) environments. In RST environments, robots have been utilized as robot storytellers [4-6]. A robot storyteller may be designed with different characters in a story by a role-playing mechanism. The robot

storyteller can interact with learners through various gestures, body postures, emotional speech, and facial expressions. The suitable HRI designs of RST may enhance learners to acquire knowledge from stories.

The development of knowledge and skills about HRI and RST have become more accessible to students than ever before [4]. The programming of a robot to utilize an RST system is usually helpful in developing students' abilities in technology comprehension (TC) [7]. TC consists of learning objectives related to computing, design, and societal reflection. The major objectives of the learning activity to students are enhancing their knowledge and skills related to: (1) computing skills, such as programming, algorithms, pattern recognition, and abstraction; (2) specifying a problem and utilizing an iterative design process to develop solutions; and (3) reflecting and evaluating the solutions. Brennan, & Resnick (2012) defined that CT involves three key dimensions: computational concepts, computational practices, computational perspectives [8]. CT as thought processes involved in formulating problems and solutions [9]. In terms of improving students' computational thinking (CT) could gain their major computing knowledge and skills on TC.

Therefore, this study developed a learning activity with robots, storybooks, and multimedia materials (e.g., text, image, animation, audio, and video) to improve students' CT knowledge and skills, and foster their TC. The college students were treated by the learning activity. This study aimed to answer the following two research questions:

RQ1: What are the effects of the learning activity on students' computational thinking skills?

RQ2: What are the effects of the learning activity on students' technology comprehension?

II. ROBOT-BASED LEARNING ENVIRONMENT AND STORYTELLING

The use of robots and physical objects to improve students' science knowledge learning is well established [10]. Lahey et al. (2008) presented scenarios of HRI for fostering students' interactions with robots. In their experiment, a robot could be a robotic pet played with learners, a robot could be an avatar

controlled by students, a robot also can be integrated into a learning environment that can be used as an educational tool [11]. A prior study designed robots as credible college instructors. They examined college students' perceptions of robot instructors in an experiment. Their findings revealed these robots that can be utilized as the information source and provide direct instruction to students [10].

Similarly, several studies confirm that storytelling can develop students' cognition, and creativity [12]. When students construct stories, they explore facts and contexts from stories, create meaningful contents, and enhance abstract concepts. According to the argument, narrative learning of storytelling is suitable for the development of particular knowledge, skills, and positive attitudes in action. Kopcha, & Ocak (2019) revealed that learners may need a variety of robotic learning activities to support their engagement in abstract thinking [13]. Learning tools such as sheet-based programming and introductory robot-based storytelling projects help learners to decompose a complex task and find solutions effectively.

We can summarize the above facts in a simple form by saying that the development of robot-based storytelling has not only affected students' narrative skills but cultivated students' CT knowledge and skills.

III. METHODS

A. Participants

The present study involved 15 college students from a university in Taipei, Taiwan. These 15 students had no prior experience with robots and storytelling project development. These students are studying in the college of management.

B. Design of the robot-based storytelling development environment

This study introduced an instructional design with robots, storybooks, and multimedia materials for improving college learners' introductory ICT knowledge, fostering their TC, and enabling them to learn and develop robot-based storytelling systems in the context of educational robots and storybooks.

The robot-based storytelling development environment includes a robot script programming server in the cloud, a robot-based storytelling editor, several robots, multimedia materials, and storybooks in a local site (Figure 1). The robot script programming server consists of a sheet-based programming editor. The sheet-based programming editor is like a template based on a google sheet that can be edited by students for creating robot-based storytelling programs in the context of educational robots and storybooks. Students can use the robot-based storytelling editor in the local site or the robot script programming server in the cloud to construct their sheet-based programs, authorize their own robot-based storytelling programs, and download to the robots through the robot-based storytelling editor in the local site.

These robots receive and execute the robot-based storytelling programs from the robot-based storytelling editor

to perform as storytelling robots. Then, the storytelling robots can tell stories with gestures, body postures, emotional speech, facial expressions, and varied multimedia contents, and interact with learners who are listening to the stories.

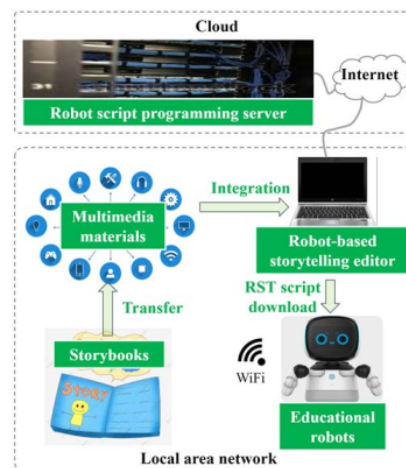


Figure 1. The development environment of robot-based storytelling

C. Learning activity of constructing robot-based storytelling system

The design of teaching and learning activities for constructing robot-based storytelling systems consists of three phases: (1) Introduction to the robot-based storytelling development environment; (2) Introduction to the sheet-based robot programming editor; and (3) Constructing of robot-based storytelling systems (Figure 2).

(1) Introduction to the robot-based storytelling development environment: In this phase, we provided a set of materials for introducing educational robots, the designed robot script programming server, and robot-based storytelling editor.

(2) Introduction to the sheet-based robot programming editor: The students started to learn how to design a sheet-based robot program and utilize multimedia materials in a robot-based storytelling system.

(3) Constructing of robot-based storytelling systems: The sheet-based robot programming editor was likely to benefit the students in developing robot programs, so that the students who might design sheet-based programs to integrate their stories, multimedia materials, facial expressions, body postures and gestures, and emotional speech for constructing robot-based storytelling systems according to their HRI analyzed results by a prepared scaffolding program

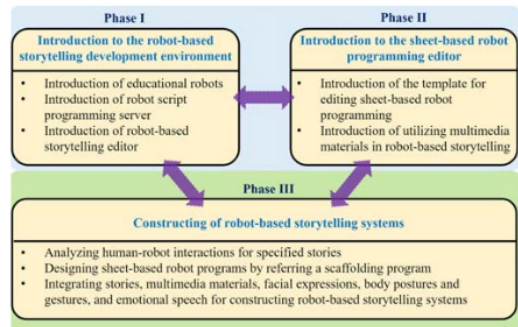


Figure 2. The design of teaching and learning activities for constructing robot-based storytelling systems.

D. Experimental procedure

We administered a computational thinking (CTt) pre-test (<https://goo.gl/GqD6Wt>), and a computational thinking skills (CTs) pre-test [14] to evaluate the students' technology comprehension (TC). We then provided a series of lecturing training and hands-on learning activities. The teaching and learning activities took six weeks (150 minutes per week). After that, the CTt and CTs were performed (Figure 3).

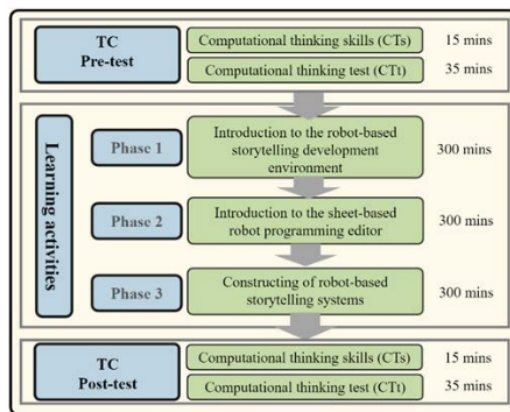


Figure 3. Experimental procedure

E. Procedure of data analysis

Data collected in this study included a pre-and a post-tests of CTs written test and CTt written test. The CTs written tests consisted of 29 multiple-choice questions and the CTt written test consisted of 28 multiple-choice questions. Each item of ¹⁶ addresses one or more computational concepts (e.g., directions and sequences, loops, conditionals, while conditional loops, and simple functions), which appear in increasing difficulty [3].

The pre-and post-tests of the CTs were evaluated on a ⁸ 5-point Likert-type scale with 1 corresponding to "strongly disagree" and 5 to "strongly agree".

The pre-test of CTt was an evaluation of the students' prior knowledge and skills about computational thinking at the beginning of the program, and the post-test was administrated to measure the learners' CT learning performance. In order to solve the problems of CTt, the students must do varied ⁷ gnitive tasks, such as sequencing an algorithm, completing an incomplete algorithm, or debugging an ¹⁷ rrect algorithm. Table 1 shows the correspondence of the ²⁸ multiple-choice questions to the items of the computational concept of CTt [3].

TABLE 1. ASSESSMENT FOR COMPUTATIONAL THINKING CONCEPT

Computational concept	Questions
Directions and sequences	1, 2, 3, 4,
Loops	5, 6, 7
Conditionals	8, 9
While conditional loops	12, 13, 21, 22
Functions	25, 26, 27
Debug	10, 11, 15, 16, 19, 20, 23, 24, 28
Algorithm	14, 17, 18

IV. RESULTS

The pre-and post-tests of CTs written test and CTt written test yielded a total of 15 learning outcomes, while the students' CT learning effects and their perceptions toward the learning activities for constructing robot-based storytelling systems answer ¹¹ the research questions. The Student's paired t-test was used to determine whether the means of the two sets of data, the pre-and post- written tests (i.e., CTs, and CTt), were paired, normally distributed, and significant ¹⁷ different from each other. The R version 4.1.0 software was used to analyze the collected data for the statistical analysis.

A. ¹⁴ The effects of the learning activity on students' computational thinking skills

In the comparisons of pre-and post- CTt written tests for learning outcomes by each student, Table 2 shows that as a whole the students had relatively increased their CT knowledge and skills with the learning activities of constructing robot-based storytelling systems. Table 2 depicts that the score of CT concept learning outcome increased from pre-test Mean = 21.81 to post-test Mean = 22.27, a composition ¹⁸ gain of 0.47 ($p = 0.67$) on all the students, indicating without a significant difference between the pre- and the post-tests.

TABLE 2. ANALYSIS OF THE LEARNERS' STEM LEARNING OUTCOME AND COMPUTATIONAL THINKING

CTt	Mean	Std	Max	Min
Pre-test	21.80	3.05	27.00	16.00
Post-test	22.27	2.94	26.00	16.00

B. The effects of the learning activity on students' technology comprehension

In the comparisons of pre-and post- CTs written tests for the perception of the learning activities for constructing robot-based storytelling systems by the students, Table 3 shows that all the students increased their CTs scores toward their learning with the robot-based storytelling development environment. The score of creativity increased from Mean = 4.01(0.85) to post-test Mean = 4.25(0.68), a composite gain of 0.24 ($p=0.02$) on all students, showing a significant improvement in their creative thinking. The score of the cooperative decreased from pre- test Mean = 4.68(0.50) to post-test Mean = 4.40(0.64), a composite gain of -0.28 ($p=0.01$).

The scores of algorithmic thinking (increased from 3.12 to 3.34), critical thinking (increased from 3.63 to 3.80), and problem-solving (increased from 2.44 to 2.62) were increased. Moreover, the overall outcome increased from pre-test Mean = 3.53(0.30) to post-test Mean = 3.67(0.46), a composite gain of 0.14 ($p=0.33$) on all students. It showed that these dimensions and the overall outcome were increased non-significantly between the pre-and the post-tests.

TABLE 3. COMPARISON OF THE PRE-AND POST-TEST OF LEARNERS' PERCEPTION TOWARD THE LEARNING ACTIVITY

	Pre-test		Post-test		Gain	
	Mean	Std	Mean	Std	Mean	p value
Creativity	4.01	0.85	4.25	0.68	0.24	0.02
Algorithmic thinking	3.12	1.07	3.34	1.10	0.22	0.17
Cooperative	4.68	0.50	4.40	0.64	-0.28	0.01
Critical thinking	3.63	0.90	3.80	0.94	0.17	0.25
Problem solving	2.44	0.95	2.62	1.18	0.18	0.27
Overall	3.53	0.30	3.67	0.46	0.14	0.33

V. DISCUSSION

The curriculum of sheet-based programming was designed for the students to integrate the robots, stories, multimedia materials, and human-robot interaction elements as a problem-solving learning opportunity. After participating in the learning tasks of constructing robot-based storytelling systems, all the students' CTt and CTs were increased. This implied that the learning activity with robots and constructing a robot-based storytelling system helped the students enhance their skills even if the effects seemed insignificant.

The first finding of this study is that the learning activities with the robot-based storytelling development environment were associated with the college students' positive TC

learning outcomes, especially connected to their capability of creativity. These learning activities provide the students with opportunities to engage in the manipulation of constructing robot-based storytelling systems, integrate story contents with ICT elements (e.g., robots, multimedia materials, and human-robot interactions), and implement programming procedures. These learning activities allowed the students to comprehend ICT knowledge and skills, and practice with real applications (Figure 4), which might raise their TC.

The second finding showed that the learning activity with constructing robot-based storytelling systems seemed to have a strange impact on the students' cooperation. The major reason might be affected by school closures due to the COVID-19 pandemic during the last 3 weeks, the students can only have classes and discuss with their team members by Google meet through the internet video-conference calls. The students did not have a chance to collaborate with their team members in the same place as their prior expectation.



Figure 4. Developments of robot-based storytelling systems: (a) designing facial expressions, (b) setting characters of a story, and (c) constructing story context.

VI. LIMITATIONS

Due to the limited number of the participants in the program and COVID-19 pandemic during the experimental interval, this study did not implement a control group when investigating the impact of TC, which may pose some limitations to the validity of the study. Future research is suggested to investigate the relationships among the students' CT, learning perceptions, and TC in a long-term formal course setting.

VII. CONCLUSIONS

This study proposed teaching and learning activities with the robot-based storytelling development environment for constructing robot-based storytelling systems in promoting students' TC. The results revealed that the proposed methods improved the students' learning outcome toward TC in terms of ICT knowledge and skills, and the positive impact on their creativity toward the robot-based storytelling development environment. Further research is needed to evaluate the long-term impacts of learning outcomes and perceptions toward the learning activities with the robot-based storytelling development environment.

3 ACKNOWLEDGMENT

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