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Effects of Type of Learning Approach and Prior Knowledge on Novices' Motivation, Self-efficacy, Task anxiety and Performance in Learning *Scratch*

Ming-Puu CHEN & Li-Chun WANG
Graduate Institute of Information and Computer Education,
National Taiwan Normal University, Taiwan
mpchen@ntnu.edu.tw, cct101wang@gmail.com

Abstract: The major purpose of this study was to examine whether providing game-play activity before learning generates positive impacts on the learners. The effects of prior knowledge (high vs. low) and learning approach (play-and-learn vs. learn-and-play) on 7-graders' *Scratch* performance was examined in this study. There were ninety-two junior high school students participated in the study. The results showed that (a) those learners received learn-and-play activity possessed higher learning motivation and self-efficacy than the learners received play-and-learn activity, but levels of task anxiety for both groups were moderate; (b) levels of learning motivation and self-efficacy for learners with high prior knowledge and learners with low prior knowledge were about the same, but learners with high prior knowledge held high task anxiety than learners with low prior knowledge; (c) performance on test and project for learners from both learning activities was about the same; finally, (d) high prior knowledge learners outperformed those learners with low prior knowledge on the post-test, but both groups achieved the same level of project performance.

Keywords: game-based learning, prior knowledge, programming concept

1. Introduction

In today's highly interactive digital world, it has been commonly recognized that all students should possess technological literacy [1]. For instance, in England, a policy that required students aged from 7 to 16 to apply computer and technology to their learning in different subjects has been implemented [2]. Moreover, a 5-year plan which required teachers to integrate information and communication technology in curricular has been implemented in Hong Kong [1]. Although computer and technology can enhance teaching and learning by applying it as a supporting tool to cultivate learners' technological literacy and facilitate learners to think independently, effective learning requires learners to engage in the learning process. A considerate design of learning approach is a key to enhance learners' engagement in the learning process. Therefore, the instructional designs of e-learning activities must contain appropriate learning approaches in order to make learning become more engaging and effective.

2. Related Literature

Learning Approach and Game-based Learning

Pedagogy, content and technology (PCT) were three aspects that could be taken into consideration when examining the barriers of technology-based learning activity in a study. According to the pedagogy perspective, learners' learning interests and learning motivation were usually neglected in programming learning [3]. Based on the content viewpoint, even syntax and programming concepts were difficult for novices to understand [4]. In connecting with the technology aspect, programming skill was one of the crucial skills for technological literacy. As Kafai, Ching and Marshall suggested, learners could benefit from the creating process when their role changed from a learner to a designer [5]. By doing so, learners would be able to overcome barriers in learning to program.

Generally speaking, game-based learning, which becomes a promising tool for providing highly motivating learning situations to learners, can be an effective means to assist learners to learn since learners construct knowledge by playing, maintain high learning motivation and apply acquired knowledge to real-life problem solving. Game-based learning enables learners to construct knowledge from trial and error with an integration of engaged playing, problem solving, situated learning and challenges [6, 7]. A successful game-based learning was strongly correlated with higher degrees of flow experience, as suggested by Kiili [8]. However, whether the sequencing of game-based learning activity affects learners' motivation and achievement remains unsolved in previous literature. Since the majority of researches related to game-based learning focused more on the theoretical aspects of gaming and lacked empirical evidence to validate its educational meaningfulness, the present study, therefore, employed an experiential gaming model as the pedagogical framework with two types of learning approaches, including play-and-learn and learn-and-play, to examine whether learners perform equally in learning programming concepts. Accordingly, the effects of learning approach and prior knowledge on learners' performance in comprehension test and project were also examined in the study.

Learning through Game-play

Through ambiguous and challenging trial and error, games-based learning can provide a rich learning context to help learners construct higher level knowledge [6]. Through the game-play processes, learners will be able to develop reflection skills and meta-cognitive strategies and transform the learning experience into problem solving. The developed cognitive strategies help learner bridge prior knowledge with new knowledge and enhance meaningful learning [9]. Therefore, the higher level programming knowledge and skills can be acquired by the learners through game-play. Moreover, different types of game strategies can be utilized to fulfill specific learning objectives. Previous studies [10, 11] suggested that action or sports games were appropriate for declarative knowledge content, adventure games were more suitable for practicing procedural knowledge, and role-play games were suitable for conditional knowledge. Hence, the present study employed matching game and challenge game to provide various types of interactivity to engage learners and facilitate learning of computer concepts and skills through the joyful gaming processes.

The ability to reconstruct knowledge, to express ideas creatively and to create information productions can be referred to as the capability of information technology, whereas technological literacy emerged in today's highly interactive digital world can be referred to as the programming skills [8]. However, novice programmers faced barriers when learning programming [12], which could be categorized into three aspects, including pedagogy, content and technology. The learning activity for programming and learners' learning interests and learning motivation were usually unmatched based on the perspective of pedagogy [3]. From the viewpoint of content, learners, especially novices, lacked practicing opportunity and had a difficult time in comprehending the syntax and concepts of programming [12]. On the other hand, skills on programming were technological literacy for problem solving based on the aspect of technology. For overcoming the barriers in learning programming, Kafai, Ching and Marshall even suggested that the role of learners should be changed from a game user to a game designer since learners could benefit from the creating process and possessed more opportunities to reconstruct acquired knowledge, express ideas and enrich learning experiences [5]. In the present study, for eliminating the barriers in learning programming, two learning approaches, learn-and-play and play-and-learn were employed and their effects on learners' attitudes and achievement were examined.

Individual Differences

Learners' individual predispositions somehow conditioned their readiness to benefit from the learning environment. Giving a certain environment to learners, some benefited more, some less and some not at all. In the field of computer skills learning, computer prior knowledge was suggested to dominate learners' performance. Individual differences in background and prior experience were found to affect the performance and attitude of users of computers [13, 14]. Prior knowledge is either a necessary or at least a facilitating factor in the acquisition of new knowledge in the same content domain. Individuals who have greater knowledge will learn more quickly and effectively. It was also suggested that domain-specific expertise is the most important difference between novices and experts in various knowledge domains, such as physics, algebra, geometry, and computers. Previous studies have shown that the most reliable predictions of computing attitude and achievement are based on the amount of prior computing knowledge [15, 16]. Therefore, it is important to examine learners' prior knowledge along with learners' performance while learning computer skills.

3. Research Methods

Research Design

This study employed a quasi-experimental design to examine the effects of learning approach and prior-knowledge on learners' performance and attitudes. The experiment was conducted in a 4-week session of learning basic programming concepts using *Scratch*. As shown in Figure 1, the play-and-learn approach employed game-play of *Scratch* games first, after that, learning activities on programming concepts using *Scratch* were provided for learners to practice their acquired knowledge and concepts. In contrast, the learn-and-play approach employed learning activities on programming concepts using *Scratch* first, then game-play of *Scratch* games were employed and served as an application context for learners to practice their acquired knowledge and concepts. After game-ply, learners needed to complete the given programming project individually. Participants' levels of prior-knowledge were obtained from their previous computer course grades and were identified as the low prior-knowledge group and the high prior-knowledge group by the mean grade. Multivariate Analysis of Variance (MANOVA) was conducted on learners' performance with a significance level of .05 in the present study.

Figure 1. *Scratch*, the left screen, was employed to serve as a learning context and tool for learning programming concepts; *Scratch* games, the right screen, served as an application context for learners to practice their acquired knowledge and concepts.

Participants

Ninety-two 7-graders participated in the experiment. All participants were novices to programming languages. Participants were randomly assigned to either the play-and learn group or the learn-and-play group. Participants' levels of prior-knowledge (high vs. low) were identified according to their grades on previous computer course. A programming project was employed to facilitate participants to apply acquired knowledge to solve real-life problems after learning from the game-play activities. Project performance was assessed for further analysis.

4. Findings

4.1 Analysis of Learning Approach on Motivation, Self-efficacy and Task-anxiety

The group means of participants' motivation, self-efficacy and task-anxiety measured on a 5-point Likert-type scale are shown in Table 1. For learning approach groups, the play-and-learn group obtained higher motivation and self-efficacy and slightly higher task-anxiety than the learn-and-play group. Similarly, for prior knowledge groups, the high prior-knowledge group obtained higher motivation, self-efficacy and task-anxiety than the low prior-knowledge group. The differences between groups were further analyzed as follows.

Table 1. Group means of participants' motivation, self-efficacy and task-anxiety

Dependent Variable	Group	Mean	SD	N
Motivation	Learn-and-Play	3.003	.816	47
	Play-and-Learn	3.492	.774	45
Self-efficacy	Learn-and-Play	2.823	.697	47
	Play-and-Learn	3.435	.817	45
Task-anxiety	Learn-and-Play	2.984	.859	47
	Play-and-Learn	3.034	.759	45
Motivation	Low PK	3.160	.723	43
	High PK	3.335	.912	49
Self-efficacy	Low PK	3.078	.735	43
	High PK	3.180	.882	49
Task-anxiety	Low PK	2.801	.709	43
	High PK	3.217	.844	49

Two-way MANOVA was conducted to examine the effects of learning approach and prior knowledge on participants' motivation, self-efficacy and task-anxiety. First, as shown in Table 2, Levene's tests of equality were not significant for all dependent measures. The null hypothesis that the error variance of the dependent variable is equal across groups was sustained. The MANOVA summary is shown in Table 3, the main effects of learning approach were significant on motivation and self-efficacy (motivation: $F_{(1,91)}$=8.506, p=.004; self-efficacy: $F_{(1,91)}$=14.545, p<.001) and the main effect of prior knowledge was significant on task-anxiety ($F_{(1,91)}$=6.367, p=.013). That is to say, the play-and-learn group revealed higher motivation and self-efficacy than the learn-and-play group, and the high prior-knowledge group possessed higher task-anxiety than the low prior-knowledge group

Table 2. Summary of Levene's tests for motivation, self-efficacy and task-anxiety

Dependent Measure	F	df1	df2	Sig.
Motivation	.154	3	91	.927
Self-efficacy	.761	3	91	.519
Task-anxiety	1.057	3	91	.371

Design: Intercept+Group+PK+Group* PK

Table 3. MANOVA Summary for group and prior-knowledge on motivation, self-efficacy and task-anxiety

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group	Motivation [a]	5.432	1	5.432	8.506	**.004**	.088
	Self-efficacy [b]	8.510	1	8.510	14.545	**.000**	.142
	Task-anxiety [c]	.055	1	.055	.089	.766	.001
Prior-knowledge	Motivation	.695	1	.695	1.088	.300	.012
	Self-efficacy	.236	1	.236	.403	.527	.005
	Task-anxiety	3.939	1	3.939	6.367	**.013**	.067
Group * PK	Motivation	.109	1	.109	.171	.680	.002
	Self-efficacy	.001	1	.001	.002	.968	.000
	Task-anxiety	.843	1	.843	1.363	.246	.015
Error	Motivation	56.191	91	.639			
	Self-efficacy	51.483	91	.585			
	Task-anxiety	54.452	91	.619			

a R Squared = .097 (Adjusted R Squared = .067)
b R Squared = .143 (Adjusted R Squared = .114)
c R Squared = .081 (Adjusted R Squared = .050)

4.2 Analysis of Learning Approach on Post-test and Project Performance

The group means of participants' post-test and project performance measured on a 10-point scale are shown in Table 4. For learning approach groups, the play-and-learn group obtained slightly higher post-test and project performance than the learn-and-play group. Similarly, for prior knowledge groups, the high prior-knowledge group obtained higher post-test and project performance than the low prior-knowledge group. The differences between groups were further analyzed as follows.

Table 4. Group means of participants' performance on post-test and project

Dependent Variable	Group	Mean	SD	N
Post-test	Learn-and-Play	7.491	2.674	47
	Play-and-Learn	7.585	2.445	45
Project	Learn-and-Play	7.317	2.244	47
	Play-and-Learn	7.727	2.448	45
Post-test	Low PK	6.380	2.226	43

	High PK	8.695	2.340	49
Project	Low PK	7.377	2.402	43
	High PK	7.667	2.306	49

Two-way MANOVA was conducted to examine the effects of learning approach and prior knowledge on participants' post-test and project performance. First, as shown in Table 5, Levene's tests of equality were not significant for all dependent measures. The null hypothesis that the error variance of the dependent variable is equal across groups was sustained. The MANOVA summary is shown in Table 6, the main effect of learning approach was not significant on dependent measures and the main effect of prior knowledge was significant on the post-test ($F_{(1,88)}$=22.904, p<.001). In other words, the play-and-learn approach and the learn-and-play approach revealed similar effects on participants' post-test and project performance. However, the high prior-knowledge group achieved higher post-test performance than the low prior-knowledge group, but both groups achieved the same level of project performance

Table 5. Summary of Levene's tests for motivation, self-efficacy and task-anxiety

Dependent Measure	F	df1	df2	Sig.
Post-test	1.623	3	88	.190
Project	.677	3	88	.569

Design: Intercept+Group+PK+Group* PK

Table 6. MANOVA Summary for group and prior-knowledge on post-test and project

Source	Dependent Variable	ype III um of quares	df	Mean Square	F	Sig.	Partial Et Squared
Group	Post-test [a]	!02	1	.202	.038	.846	.000
	Project [b]	80.388	1	380.388	.681	.411	.008
Prior-knowledge	Post-test	21.806	1	121.806	22.904	.000	.207
	Project	89.994	1	189.994	.340	.561	.004
Group*PK	Post-test	.526	1	2.526	.475	.492	.005
	Project	96.870	1	196.870	.353	.554	.004
Error	Post-test	67.994	88	5.318			
	Project	9144.098	88	558.456			

a Adjusted R Squared = .183
b Adjusted R Squared = .015

5. Conclusions

Although game-based learning has become a promising activity for providing highly motivating learning to learners, whether the sequencing of game-based learning activity affects learners' motivation and achievement remain unsolved in previous literature. The present study examined the effects of different sequencing on learners' attitudes toward game-based learning and performance in learning from game-based learning by the play-and-learn and learn-and-play learning approaches. The results of this study suggested that the play-and-learn approach can trigger higher motivation and self-efficacy than the learn-and-play approach, and at the same time both approaches help learners maintain at a moderate level of task-anxiety that engaged learners in the game-play learning task. As for prior knowledge, both low prior-knowledge learners and high prior-knowledge learners revealed same levels of motivation and self-efficacy. The possible cause may result from the promising feature of game-based learning in promoting learning motivation and self-efficacy through motivated learning-by-doing activities. For task-anxiety, probably due to the high prior-knowledge learners' better-structured elaborated knowledge, they showed higher concern in completing the game-play task than the low prior-knowledge learners. Therefore, learners with high prior-knowledge may be better to benefit from the game-based learning activities.

As for learning achievement, the play-and-learn approach and the learn-and-play approach revealed similar effects on post-test and project performance. In other words, both the play-and-learn approach and the learn-and-play approach are effective in achieving the same levels of performance. However, the high prior-knowledge group achieved higher post-test performance than the low prior-knowledge group, but both groups achieved the same level of project performance. That is to say, although the low prior-knowledge learners acquire lower comprehension in programming concept, they achieve the same performance level as the high prior-knowledge learner in the hand-on programming project. Therefore, it can be inferred that the learning-by-doing game-play activities can better facilitate learners to apply acquired knowledge in the learning contexts.

In conclusion, game-based learning can be an effective means to assist learners to construct knowledge by playing, maintain high learning motivation and apply acquired knowledge to real-life problem solving. The present study further suggested that applying play-and-learn approach can facilitate learning and, at the same time, maintain high motivation and self-efficacy

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