

***Effects of Games for Enhancing Executive Function Program on Preschoolers:
Mediational Role of Executive Function Skills***

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Abstract

Executive function (EF) skills has been highlighted as a potential factor for many cognitive development. One of the most important cognitive indicator for the transition to school is early academic achievement which includes mathematical and reading skills in preschoolers. However, it has been less explored on how to establish EF skills through daily school program. The current research created a 4-week EF skills training program through playing games for preschoolers (Games for Enhancing Executive Function – GEEF program) which integrates the executive function main domains: inhibitory self-control, flexibility, and emergent metacognition with Piaget's type of play called game with rules. Participants were 120 typically developing 5-year-olds from kindergartens in Ratchaburi, Thailand, divided into two groups: experimental group implemented with GEEF program and control group with normal school activities. The result indicates that GEEF program can significantly improve the experimental group early academic achievement comparing with control group. The research also suggests that EF skills may be one mechanism which helps increase early academic achievement in preschool children.

Keywords: executive function skills, early childhood development, inhibitory control, flexibility, meta-cognition

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Introduction

Preschool education is important for the transition to formal school as crucial skills are developed during this period. One of the most predictive factor for school readiness and later school success is early academic achievement which include early mathematical and reading skills (Schweinhart, Montie, Xiang, et al. 2005; Lonigan, Burgess, & Anthony. 2000; Diamond, Barnett, Thomas, & Munro. 2007). The early mathematical skills are 1) numeracy 2) measurement 3) geometry and spatial ability and 4) logical thinking. The early reading skills include 1) letters knowledge 2) phonological awareness 3) vocabulary and 4) symbol understanding.

According to many recent research, executive function (EF) skills has been highlighted as a potential factor for many cognitive development, including early academic achievement. The executive function domains evidentially emerged in preschool age are 1) Inhibitory self-control 2) Flexibility and 3) Meta-cognition which includes working memory, and planning and organizing. (Blair & Razza. 2007; Bull, Espy, & Wiebe. 2008; Lan, Legare, Ponitz, Li, & Morrison. 2011; Vandenbroucke, Verschueren, & Baeyens. 2017).

In the past two decades, there are many researches focusing on how to assess the executive function skills in preschool age children (Garon, et al. 2008; Anderson. 2002; Jacques, & Zelazo. 2001; Espy, et al. 2001; Zelazo. 2006). However, the study about how to integrate executive function skills practice in curriculum for preschoolers to enhance other cognitive development needed for school readiness is still limited.

In this research, the Games for Enhancing Executive Function Program (GEEF Program) was created by integrating all the domains of executive function emerged in preschool age children (Isquith, et al. 2005) with playful activity adopted from Piaget's game with rules (Piaget. 1962). The pretest and posttest of early academic achievement and executive function skills were applied. Also, the executive function skills were tested for the mediational effects between the GEEF program and the early academic achievement in preschoolers.

Research Method

The study applied the quasi-equivalent control group design (Campbell. 1971) with the pretest to test the equivalence between the experimental and control group and the posttest to test the differentiation between both groups after implemented the experimental group with the GEEF program.

Participants

This study was implemented in 2 kindergartens in Ratchaburi Province, Thailand. The second-year kindergarteners were in the second semester of the school year 2016 and they were about to be the first graders of the primary school next semester. The participants in this study were 120 typically-developed second-year kindergarteners (60 boys and 60 girls) divided equally into 2 groups: experimental group implemented with GEEF program and control group with normal school activities. Age of the participants were between 64-77 months ($M=71.39$). For the experimental group,

parents were asked for cooperation in their children attendance at the program which took place in the normal classroom during the school time.

Instruments

Games for Enhancing Executive Function Program (GEEF Program)

The program used in this study was the integration between executive function domains (inhibitory self-control, flexibility, working memory, and planning and organizing) and playful activities which includes 6 games with rules according to Piaget's types of play classified by cognitive complexity. The games used in the program were selected by the following criteria: 1) attractive to children 2) developmentally appropriated 3) in accordance with the executive function main domains and 4) adjustable for simple and more complex rules.

This 30-minute-session program consists of 3 phases: 1) Introduction to the games (2 sessions) 2) Simple rules phase (5 sessions) and 3) Advance rules phase (5 sessions). The program was implemented 3 times per week, 12 sessions in total.

In the introduction phase, the participants in the experimental group were told stories related to each game, combined with the rules of the game. Then, it was followed by the simple rules phase in which the children could choose the game they were interested to play. After finished all the simple rules phase, the program moved on to the advance rules phase in which the rules of each game became more complex and required more skills.

Early Academic Achievement Test

The early academic achievement test consisted of 2 parts: early mathematical skills test and early reading skills test. Both parts were based on Thailand national preschool curriculum. The early mathematical skills are 1) numeracy 2) measurement 3) geometry and spatial ability and 4) logical thinking. The early reading skills include 1) letters knowledge 2) phonological awareness 3) vocabulary and 4) symbol understanding. The test was used with both experimental and control group, before and after the implementation of the GEEF program.

The early academic achievement test was conducted on 100 second-year kindergarteners which were not the participants in the study. The reliability, difficulty and discrimination of the test was tested. The Alpha Cronbach's coefficient of reliability of the total test was .91. The total test was also in adequate level of difficulty ($M=.74$) and discrimination ($M=.30$)

Executive Function Skills Test

The executive function skills test used in this study was developed from the Head-Toes-Knees-Shoulders Tasks (HTKS) (Ponitz, et al. 2009). The test was translated into Thai version and the tasks were thoroughly analyzed with all the main domains of executive function. This test was selected to measure the executive function skills as it is appropriate for teacher use and school context.

The test is the direct behavioral observation test. Children were asked to do the opposite of what they heard. The correct responses gained 2 points; the incorrect responses gained 0 point and if the children self-corrected with the correct action, they gained 1 point. There are total 20 items and scores ranged 0 to 40.

Results

The Equivalence Between Groups

Before the implementation of the GEEF program, the early academic achievement and executive function skills of both groups were tested to analyze the equivalence between the groups. The dependent sample t-test analysis was adopted. The result showed that both group had no significant difference in every factor as shown in Table 1, indicated that both groups were equivalent.

Factor	Experimental Group (n=60)		Control Group (n=60)		t	Sig. (2-tailed)
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Early academic achievement						
- Early mathematical skills	13.62	1.32	14.25	2.62	-1.681	.095
- Early reading skills	13.17	3.34	13.55	3.02	-.660	.511
Executive function skills	13.47	6.04	13.27	6.77	.171	.865

Table 1: Comparing pretest means of early academic achievement and executive function skills between experimental and control group

Comparing Posttest Means Between Groups

After the implementation of the GEEF program in the experimental group, the early academic achievement and executive function skills of both groups were tested again to analyze the difference between groups. The dependent sample t-test analysis was adopted. The result showed that the experimental group early mathematical skills means was significantly higher than the control group at level .01, as well as executive function skills, and the early reading skills means in the experimental group was significantly higher than the control group at level .05, as shown in Table 2.

Factor	Experimental Group (n=60)		Control Group (n=60)		t	Sig. (2-tailed)
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Early academic achievement						
- Early mathematical skills	15.99	2.30	13.94	3.89	3.511**	.001
- Early reading skills	15.04	3.03	13.92	3.11	1.988*	.049
Executive function skills	17.83	4.55	13.48	6.57	4.216**	.000

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

Table 2: Comparing posttest means of early academic achievement and executive function skills between experimental and control group

Mediational Role Analysis of Executive Function Skills

The matrix of correlation between each variable was utilized to test that the variables had no multicollinearity condition which could cause the decreasing of the efficiency in predicting or describing the dependent variable (Kline. 2005). Moreover, the group variables, which were nominal scale, were represented with dummy variables: 0 for control group and 1 for experimental group. The results of Pearson's correlation coefficient between 7 variables were shown in Table 3.

Variables	1	2	3	4	5	6	7
1. Group: experimental/control	1.000						
2. Math_T1	-.153	1.000					
3. Reading_T1	-.061	.240**	1.000				
4. EF_T1	.016	.373**	.324**	1.000			
5. Math_T2	.308**	.516**	.328**	.277**	1.000		
6. Reading_T2	.180*	.324**	.650**	.650**	.518**	1.000	
7. EF_T2	.362**	.341**	.230*	.474**	.465**	.338**	1.000

Note: Math=Early mathematical skills, Reading=Early reading skills, EF=Executive function skills, T1=Pretest, T2=Posttest

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

Table 3: Correlations between 3 cognitive variables, pretest and posttest, and group variable

As shown in Table 3, paired data of group variable and executive function skills was not exceed .85, indicated that there is no multicollinearity condition. The correlation coefficient between executive function skills and early academic achievement ranged .303 to .432, indicated that the relationship between variables were linear correlation which proved that executive function skills significantly correlated with early academic achievement.

According to the testing for mediation diagram as shown in Figure 1, the regression analysis was implemented to test the mediational effect of executive function skills between the GEEF program and the early academic achievement in four steps (Baron, & Kenny. 1986) as shown in Table 4. The results of the mediational analysis as shown in figure 2 and 3.

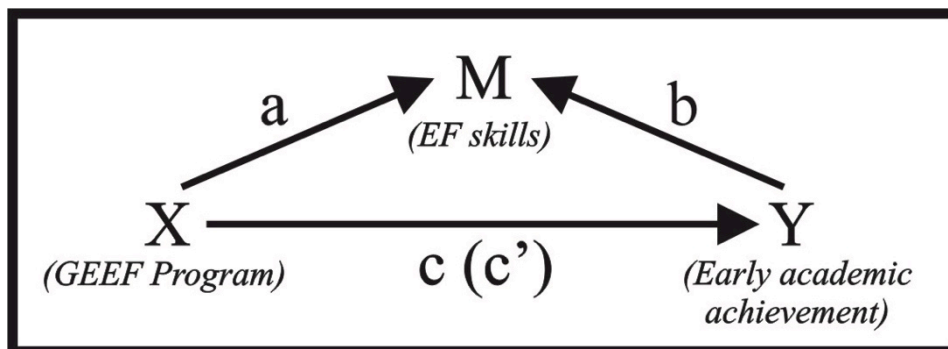


Figure 1: Mediational analysis diagram

Step	Analysis	Diagram
1	Conduct a simple regression analysis with X (group variable) predicting Y (early academic achievement) for path c alone, $Y = B_0 + B_1X + e$	$X \xrightarrow{c} Y$
2	Conduct a simple regression analysis with X (group variable) predicting M (EF skills) for path a , $M = B_0 + B_1X + e$	$X \xrightarrow{a} M$
3	Conduct a simple regression analysis with M (EF skills) predicting Y (early academic achievement) for path b alone, $Y = B_0 + B_1M + e$	$M \xrightarrow{b} Y$
4	Conduct a multiple regression analysis with X (group variable) and M (EF skills) predicting Y (early academic achievement), $Y = B_0 + B_1X + B_2M + e$	$X \xrightarrow{c'} Y$ $M \searrow b$

Table 4: Meditational analysis steps

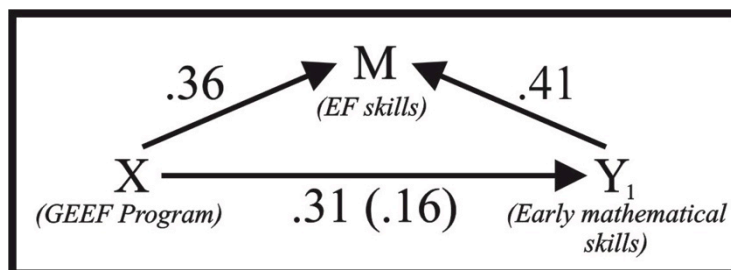


Figure 2: Results diagram of mediational analysis between GEEF program, executive function skills and early mathematical skills

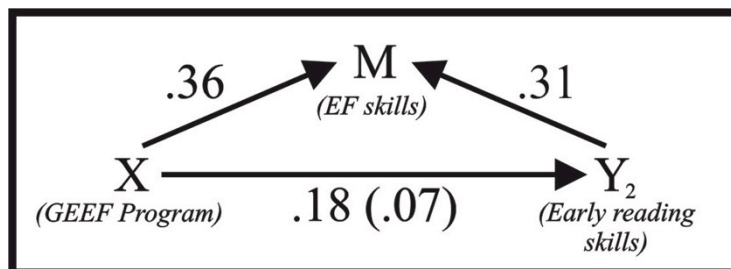


Figure 3: Results diagram of mediational analysis between GEEF program, executive function skills and early reading skills

Conclusions

This quasi-experimental study was intended to examine the efficiency of the GEEF program on the early academic achievement in preschoolers and to study the mediational role of executive function skills that lied in between the GEEF program and the early academic achievement. The program was created based on all main domains of executive function that emerged during preschool age, combined with playful activity which is developmentally appropriate based on Piaget's theory of play categorized by cognitive development: game with rules (Piaget. 1962).

Before the implementation of GEEF program, both experimental and control group were the equivalent in early academic achievement and executive function skills, confirmed by the pretest results. After all the 12 sessions of the GEEF program were finished, the posttest results showed that the GEEF program was efficient as the experimental group gained significantly higher scores in early academic achievement and executive function skills than the control group. These findings support the hypothesis that the GEEF program contributed of executive function main domains can enhance both executive function skills and early academic achievement in preschoolers.

In agreement with the literature, there is relationship between executive function skills and early academic achievement, both in early mathematical and reading skills (Blair & Razza. 2007; Bull, et al. 2008; Lan, et al. 2011; Vandenbroucke, et al. 2017). As the correlation coefficient analysis found that in pretest and posttest, both variables were significantly and positively correlated. Although, the correlation coefficient between executive function skills and early mathematical skills is higher than the early reading skills. Moreover, the mediational analysis confirmed the relationship between these two variables, suggested that the executive function skills effect the early academic achievement as complete mediator between the GEEF program and the early academic achievement.

Research Implications

The present research is the sample of how to integrate the developmentally appropriate activities that can enhance executive function skills in preschool curriculum as these skills are crucial for many cognitive development, including the early academic achievement which can predict the school readiness and later school success. Also, the integration of executive function skills can be extended to more variety of activities to help improve the quality of preschool curriculum in the future.

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