Iranian Evolutionary Educational Psychology Journal
IEEPJ
University of Hormozgan
Online ISSN: 2588 - 4395
Homepage: https://ieepj.hormozgan.ac.ir

The Effect of Gamification-Based E-Learning on Cognitive Engagement and Flexibility of School Children

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Article Info

Article type:
Research Article

Article history:
Received 14 Aug. 2023
Received in revised form 29 Feb. 2024
Accepted 5 Dec. 2024
Published online 01 Mar. 2025

Keywords:
E-Learning,
Gamification,
Cognitive Engagement,
Cognitive Flexibility

ABSTRACT

Objective: This study aims to assess the effect of gamification-based e-learning on the cognitive engagement as well as cognitive flexibility of schoolchildren.

Methods: The research methodology is semi-experimental with a pretest-posttest control group design. The population consists of all primary schoolchildren in the city of Bavānāt during the 2022-2023 school year. The sample is comprised of 40 Grade IV schoolchildren, who were selected by multistage cluster sampling and then randomly replaced in the test and control groups. To collect data, the Biggs, Kember and Leung (2001) cognitive engagement and the Dennis and Vander Wal (2010) cognitive flexibility questionnaires are used. In order to test the research hypotheses, the Multivariate Analysis of Covariance (MANCOVA) is used. And the SPSS26 software is used for data analysis.

Results: The research findings showed that by controlling the pretest effect, there is a significant difference between the posttests of test and control groups in the cognitive engagement (f=2.884) and cognitive flexibility (f=5.069) variables (P<0/0001).

Conclusions: The gamification of e-learning can help improve the cognitive engagement and flexibility of schoolchildren.

Cite this article: Mahmoudi, S., Sharafi, M. & Khalaj, M. (2025). The effect of gamification-based e-learning on cognitive engagement and flexibility of school children, *Iranian Evolutionary Educational Psychology Journal*, 7 (1), 307-318.

DOI: https//doi.org/ 10.22034/7.1.307

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Publisher: University of Hormozgan.
DOI: https// doi.org/ 10.22034/7.1.307

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[DOI: 10.22034/7.1.307]

Introduction

One of learner-based methods to make learning and education appealing is gamification. Gamification is a process in which game elements (e.g. role-playing, rules, cooperation, competition, sustainability, problem solving, feedback and sources for upgrade or progress) are used in non-game contexts like classroom activities to enhance engagement at classrooms (Deterding et al., 2011; Armier, Shepherd, Skrabut, 2016). Simões, Redondo, Vilas (2013) believe that if electronic learning is gamified it can create motivation and interest in learners and engage them in the process of learning. Gamification can bring about to plenty of advantages at classrooms with the most important being enhanced engagement of schoolchildren in learning (Kusuma et al., 2018; Da Rocha, Gomes, de Melo Filho, 2016).

Gamification is a relatively new and widely-used ICT-based approach aimed at creating human motivations and of late, researchers have embarked on relevant studies and promoted concepts pertaining to gamification in the education sector (Sanchez, D. R., Langer, M., & Kaur, 2020). Two variables associated with gamification are cognitive engagement and flexibility. Cognitive engagement is a parameter of school engagement, which has been focused upon in most research as the main parameter. In fact, to succeed, the learner is required to be engaged cognitively in school affairs in addition to behavioral engagement (Walker et al., 2006; Linnenbrink & Pintrich, 2020). Cognitive engagement refers to an individual's voluntary efforts to understand and master challenging tasks (Fredricks, Blumenfeld, Paris, 2004). Cognitive flexibility involves the ability to build or rebuild personal knowledge in different ways in order to respond to contextual needs as well as the to the human’s ability to adapt the cognitive processing strategies to face new and unexpected conditions in the environment (Haglund, 2007; Cañas, Quesada Antolí, Fajardo, 2003). Cognitive flexibility is one of the effective factors on how to react to pressure factors, which is investigated in theories studying cognition based on thought, attitude, and similar cognitive processes in behavior explanation (Delano-wood, 2002; Önen, Koçak, 2015; Spiro Jehng, 1990). Given the significance of the issue, numerous research has thus far been conducted to examine the effect of gamification on psychological structures. Mohammadi, Khoshneshin & Mohammad-Hassani (2022) have laid emphasis on the positive effect of gamification on learning and motivation in mathematics. Faregh, Saffari & Jafari (2021) demonstrated that gamification has a positive effect on learning the conflict management. Heidari & Hosseini (2021) underscored the

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[DOI: 10.22034/7.1.307]

effectiveness of gamification-based education on the curiosity of schoolchildren. Dehqanzadeh et al. (2020) showed that gamification-based e-learning positively affects the school engagement of learners. And Safaei-Movahed & Rikhtegarzadeh (2018) underlined the effectiveness of using gamification in the motivation and learning of individuals. The cited research as well as other research conducted on this matter shows that the effect of gamification of e-learning on cognitive engagement and flexibility has not been examined yet. Given the significance of these concepts in school success, our research focuses on the effect of gamification-based e-learning on the cognitive engagement and flexibility of primary schoolchildren.

Material and Methods

The research methodology was semi-experimental with a pretest-posttest control group design. The population consisted of all primary schoolchildren in the city of Bavānāt during the 2022-2023 school year. Due to the big size of the population and unavailability of a full list thereof, multistage cluster sampling was used, according to which all primary schools in Bavānāt were listed and then two Grade IV classrooms were chosen as the test group (20 pupils) and the control group (20 pupils). The test and control groups had already been homogenized by school officials in terms of educational, economic, social and cultural variables. Finally, the data was analyzed using multivariate covariance analysis with spss software version 26.

Assessment Tool

Biggs, Kember and Leung cognitive engagement questionnaire (2001): This questionnaire is the revised version of Biggs' Study Process Questionnaire Manual (1987). The instrument was revised y Biggs, Kember and Leung (2001) to assess surface and deep approaches. This questionnaire has been used in various research and its reliability and validity have been endorsed. In their research, Biggs, Kember and Leung (2001), using Cronbach's alpha, reported the reliability of surface and deep approaches at 0.64 and 0.72 respectively. Fatehi & Shokri (2014) studied the reliability of this questionnaire in Iranian society. Using single-group confirmatory factor analysis, they showed that in the whole sample and in both genders, the first-order four-factor study process questionnaire (R-SPQ-2F) including deep motivation, deep strategy, surface motivation and surface strategy had a good fit with the data.

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[DOI: 10.22034/7.1.307]

Cognitive flexibility questionnaire: This questionnaire is designed by Dennis and Vander Wal (2010). It is a brief 20-item self-report instrument used to measure a type of cognitive flexibility that is necessary for a person's success in challenging and replacing ineffective thoughts with more effective ones (Dickstein et al., 2017). The concurrent validity of this questionnaire with the Beck Depression Inventory was equal to -0.39 and its convergent validity with Martin and Rubin's cognitive flexibility scale was 0.75. Cronbach's alpha coefficient was reported at 0.90 for all the scales and 0.87, 0.89, and 0.55 for subscales respectively. In the Farsi edition, unlike the main scale which yielded only two factors, the cognitive flexibility questionnaire consists of three factors, i.e. perception of controllability, perception of various options and perception of behavior justification (Soltani et al., 2013).

Method of Application

First, two Grade IV classrooms were chosen, divided into the test group (20 persons) and control group (20 persons), to fill out the cognitive engagement and flexibility questionnaires. Then, gamification-based e-learning was applied. For this purpose, the Misha & Koosha application, available in Google Play, was used. These games were run in eight 40-minute sessions. The education content was the same for both groups with the only difference that in the test group, education was based on the Misha & Koosha education games. After education of test and control groups, the posttest was run to assess the effect of gamified education. Confidentiality of research subjects' information, their consent, nondisclosure of information and creating a reassuring atmosphere were among the ethical considerations of this research.

Data Analysis

The data analysis section includes descriptive and inferential findings. The first part is focused on the description of samples and the research variable descriptive statistics. In descriptive analysis, the data about the descriptive statistics indicators of scores obtained from the learning test (pretest and post-test) has been calculated for both groups. In the second part, covariance analysis the inferential method was used to test the research hypotheses, i.e. generalizing the results obtained from the sample to the research population.

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Results

Table 1 data provides the mean and standard deviation of subjects for the variables of cognitive engagement (deep engagement, surface engagement and cognitive engagement parameters) and cognitive flexibility (perception of option, perception of controllability, perception of behavioral justification and flexibility parameters) in the test and control groups.

Table 1. Mean and standard deviation of cognitive engagement and cognitive flexibility scores and their parameters in both test and control groups in pretest and posttest

Variable	Component	Group	Test	Number	Mean	SD	Variance	Score Range
Cognitive Engagement	Deep Engagement	Control	Pretest	20	18.80	1.54	2.37	16-22
			Posttest	20	26.75	1.77	3.14	23-30
		Test	Pretest	20	14.30	2.36	5.58	32-39
			Posttest	20	23.95	2.43	5.94	40-45
	Surface Engagement	Control	Pretest	20	25.10	1.86	3.46	32-39
			Posttest	20	41.55	1.46	2.15	40-45
		Test	Pretest	20	28.50	3.76	14.15	21-36
			Posttest	20	35	4.35	18.94	29-44
	Cognitive Engagement	Control	Pretest	20	71.05	3.77	14.26	64-78
			Posttest	20	85.40	6.58	43.30	74-95
		Test	Pretest	20	58.45	5.36	28.78	44-69
			Posttest	20	80.35	4.13	17.08	73-86
Cognitive Flexibility	Perception of Option	Control	Pretest	20	51.45	8.05	64.89	36-62
			Posttest	20	60.40	7.36	54.25	46-69
		Test	Pretest	20	32.15	6.29	39.60	23-44
			Posttest	20	42	5.56	30.94	33-54
	Perception of Controllability	Control	Pretest	20	42.75	7.66	58.72	28-52
			Posttest	20	52.45	7.72	59.62	38-63
		Test	Pretest	20	24.85	3.54	12.55	18-30
			Posttest	20	36.75	3.95	15.67	28-45
	Perception of Behavioral Justification	Control	Pretest	20	11.05	1.60	2.57	9-14
			Posttest	20	24.90	2.80	7.88	19-29
		Test	Pretest	20	7.95	2.37	5.62	4-12
			Posttest	20	22	2.51	6.31	17-26
	Flexibility	Control	Pretest	20	11.05	1.60	2.57	9-14
		Test	Posttest	20	24.90	2.80	7.88	19-29
		Control	Pretest	20	7.95	2.37	5.62	4-12
		Test	Posttest	20	22	2.51	6.31	17-26

Hypothesis 1: Gamification-based e-learning is effective in the cognitive engagement of schoolchildren

In this pretest-posttest research, Multivariate Analysis of Covariance (MANCOVA) was used for data analysis as well as pretest-posttest effect control. In this type of analysis, certain conditions need to be fulfilled to render the results reliable. We used the Shapiro-Wilk test, the Kolmogorov-

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Smirnov test, Levene's test and the regression slope test to assess the normality of the negative emotionality variable.

Table 2. Cognitive engagement normality test results

Variable	Kolmogorov-Smirnov Test			Shapiro-Wilk Test		
	Statistic	DF	P	Statistic	DF	p
Cognitive Engagement	0.097	40	0.2	0.972	40	0.41

Table 2 provides the results of Kolmogorov-Smirnov and Shapiro-Wilk tests for cognitive engagement. Given the significance level, which is higher than 0.05, it can be concluded that this variable has a normal distribution.

Table 3. Results of Levene's Test for measuring the equality of error variances of cognitive engagement

F value	DF1	DF2	P
37.087	1	38	0.23

Given the significance level of 0.05 obtained from Levene's test, data distribution is deemed to be normal.

To test the first hypothesis of the research, which examines the effect of gamification-based e-learning on the cognitive engagement of schoolchildren, the results of Table 4, i.e. MANCOVA between-group tests, were used. Table 4 provides the most important MANCOVA results, showing thee significance or non-significance of the model as well as the effect of the independent gamification-based e-learning variable on the dependent cognitive engagement variable.

Table 4. Between-group effects tests based on the effect of gamification-based e-learning on cognitive engagement

Source	Dependent Variable	SS	DF	MS	F value	p
Group	Cognitive Engagement	56.078	1	56.087	2.884	0.00
Test	Cognitive Engagement	427.697	1	427.697	21.989	0.00
Group*Test	Cognitive Engagement	676.374	2	338.187	17.235	0.00

According to Table 4, the effect of the gamification-based e-learning variable is such that the cognitive engagement variable has significance difference (F=2.884, P=0.00 for cognitive engagement). It means that statistically speaking, the mean score for cognitive engagement differs between learners. Therefore, gamification-based e-learning has had a positive effect on cognitive engagement.

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As far as the effect of tests (pretests and posttests) on cognitive engagement is concerned, a difference in the mean score is observed between learners, implying that e-learners showed difference in pretest and posttest.

Hypothesis 2: Gamification-based e-learning has an effect on the cognitive flexibility of schoolchildren.

In this pretest-posttest research, MANCOVA was used for data analysis as well as pretest-posttest effect control. In this type of analysis, certain conditions need to be fulfilled to render the results reliable. We used the Shapiro-Wilk test, the Kolmogorov-Smirnov test, Levene's test and the regression slope test to assess the normality of the negative emotionality variable.

Table 5. Cognitive flexibility normality test results

Variable	Kolmogorov-Smirnov Test			Shapiro-Wilk Test		
	Statistic	DF	P	Statistic	DF	p
Cognitive Flexibility	0.888	40	0.2	0.988	40	0.41

Table 5 provides the results of Kolmogorov-Smirnov and Shapiro-Wilk tests for cognitive flexibility. Given the significance level, which is higher than 0.05, it can be concluded that this variable has a normal distribution.

Table 6. Between-group effects tests based on the effect of gamification-based e-learning on cognitive flexibility

Source	Dependent Variable	SS	DF	MS	F value	p
Group	Cognitive Flexibility	111.546	1	111.546	5.069	0.03
Test	Cognitive Flexibility	4241.267	1	4241.267	192.730	0.00
Group*Test	Cognitive Flexibility	206.15.926	2	9103.463	442.337	0.00

According to Table 6, the effect of the gamification-based e-learning variable is such that the cognitive flexibility variable has significance difference (F=5.069, P=0.03 for cognitive flexibility). It means that statistically speaking, the mean score for cognitive flexibility differs between learners. Therefore, gamification-based e-learning has had a positive effect on cognitive flexibility.

Discussion

The main purpose of this research was to examine the effect of gamification-based e-learning on the cognitive engagement and flexibility of schoolchildren. Our findings showed that designing

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gamification-based e-learning has a positive effect on the cognitive engagement and flexibility of schoolchildren. These findings are consistent with those obtained by Mohammadi, Khoshneshin & Mohammad-Hassani (2022), Faregh, Saffari & Jafari (2021), Heidari & Hosseini (2021) and Dehqanzadeh et al. (2020).

These findings show that gamification can help introduce attractive games into a wide range of activities from boring activities to education courses, much less present education materials in an emotional and practical manner. Therefore, gamification can make the learning experience more effective. Schoolchildren's activity in a gamified environment engages them further, exposing them longer to the process of learning. Enigmatic situations and questions keep the learner's mind permanently active in search of answer. It can be then stated that gamifying the process of learning makes attendance in education courses more attractive and challenging for learners, thereby enhancing their motivation for learning concepts and skills presented in the courses. Therefore, by enhancing knowledge, skills and capability of learners, their efficiency and effectiveness will increase in fulfilling educational tasks and activities, which will subsequently upgrade their performance significantly. The social cognition theory in psychology is consistent with the concept of gamification in this context. Whereas social cognition deals with convergence in socially and environmentally mutual relations, gamification is looking for an ideal situation combining the elements of gamification with social interactions, which will reengage people in fulfilling obligations. Social interactions constitute a key factor in gamification changes. Wherever there are social communications in gamified mechanisms, systems become more effective and the spirit of self-discovery and the sense of motivation and satisfaction rises among learners. In the process of math learning with gamification, schoolchildren enthusiastically attend courses and struggle passionately and emotionally to get better scores. Furthermore, they are more inclined to collectively join the teaching-learning process. In fact, using gamification in education modifies the boring atmosphere of math courses and makes schoolchildren more dynamic and active. Gamification in e-learning can expose children to challenges with a view to creating specific cognitive skills in them with the games being both entertaining and educative. Since education through computer games pushes children to search, it would boost attention as well as cognitive engagement and flexibility. Moreover, e-learning gamification helps learners analyze their surroundings more effectively and get a better understanding of the environment they live in.

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Gamification in e-learning, presenting engaging, all-encompassing and effective experiences to learners, helps children look into issues and events from various aspects and fill voids between received data with a more comprehensive vision and enhance their thinking organization. A child's intellectual adjustment with the environment enhances cognitive engagement and flexibility. This research had limitations. It was carried out exclusively on Grade IV schoolchildren, thereby requiring caution in generalizing the results to other age groups. This research was limited to math and therefore caution is needed in generalizing the results to other courses. In this research, only one gamified environment was used for math, which again requires caution in generalizing the results to other software.

Based on the results of this research, education officials are suggested to prepare the ground for teachers to learn how to design gamification-based learning in order to benefit from the varying capabilities of gamification-based learning in their classrooms. It is also suggested that the effect of gamification-based e-earning on math anxiety and math motivation be studied.

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[DOI: 10.22034/7.1.307]

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by ethics committee of Payame Noor University.

Author contributions

All authors contributed to the study conception and design, material preparation, data collection and analysis. All authors contributed to the article and approved the submitted version.

Funding

The authors did (not) receive support from any organization for the submitted work.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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