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Research on Mathematical Computation Training Based on Gamified Adaptive Learning System

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Abstract: *With the development of technology, the use of adaptive learning systems to support learners' learning has become a hot research topic in recent years. However, as a key factor to realize adaptive learning systems, learner characteristics are often ignored, which will lead to students' low interest, poor experience and unsatisfactory learning performance in the learning process. Therefore, a gamified adaptive learning system is designed to guide students to be more active and effective in their learning. The system uses visual reinforcement, adaptive pushing and some other functions to improve students' learning processes and enhance their learning emotions, thereby influencing their learning performance. The experimental results show that the incorporation of gamification strategies can enhance learners' performance and make the advantages of adaptive learning environments work better for learners.*

Keywords: *Gamification, Adaptive Learning System, Learning Performance*

1. Introduction

An adaptive learning system is a personalized learning platform that can adapt to students' learning abilities, proximal development zone, learning preferences and other aspects[1], which can provide an adaptive learning environment to support and assist students' adaptive learning. The emergence this year of technologies such as artificial intelligence, big data analysis and cloud computing that can provide personalized interventions and guidance to learners' learning, which has made the use of adaptive learning systems to support learners' learning become a research hotspot in recent years.

In essence, adaptive learning system is a kind of online learning environment supporting personalized learning. It according to the differences of learners in the learning process (due to people or time) to provide learning support suitable for learners' characteristics[2]. Therefore, the learner characteristics of an adaptive learning system is the key to its functionality. Different scholars have different views on it: according to Professor Brusilovsky Peter, learner characteristics include learner knowledge, interests, goals, background and personality traits[3]. Some scholars in China point out that learner characteristics include learning goals, learning styles, background knowledge, learning experiences, confidence, motivations and so on[4]. Combined with current relevant research, the author believes that learner characteristics in adaptive learning systems mainly include: learner knowledge, learning styles, learning emotions (interest, motivation, anxiety level) and so on.

However, most of the current research on learner characteristics in adaptive learning systems focuses more on the learner's knowledge experience and the impact of the system on subject performance. For example, Cai et al. compared several mainstream adaptive learning systems in China and abroad and pointed out that domestic adaptive learning systems only focus on the adaptation of students' knowledge but neglect the adaptation of learning styles and emotions, and that the study emphasized that providing students with good learning experiences is a part that should be the focus of future domestic research[5]. Some researchers have also mentioned in their empirical studies that after using adaptive learning systems, there are some cases where students may not have high confidence in learning, have no sense of accomplishment, and even have a sense of frustration[6, 7].

In adaptive learning systems, the influence of learner characteristics on learning performance is a factor that cannot be ignored. How to enhance learners' learning experiences and emotions in adaptive learning systems is a question that deserves further consideration. Therefore, this study explores the integration of game strategies into adaptive learning systems so that students can take full advantage of

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gamified adaptive learning systems for better learning experiences and performance.

2. Research Design and Methods

Based on the current situation of relevant research, this study integrates game elements into an adaptive learning platform in an attempt to further promote students' learning performance by improving their learning experience. This study takes mathematical computation training as the main content, using the Mathematical Computation Test Paper, the Learning Engagement Scale and the Cognitive Load Scale as data sources in order to explore the changes that occurred in the students during the experiment.

2.1. Participants and Procedures

This experiment was conducted with 89 students. Due to students dropping out of the training for personal reasons and the removal of invalid data, the final number of students remaining was 71. The experimental process is divided into four stages: preparation, grouping, learning and data collection and analysis. And the experimental process is shown in the Figure 1 below.

In the preparation stage, students' basic information is collected and pre-test is carried out. In the grouping stage, students are divided randomly into game group (n=37) and non-game group (n=34). The game group is required to use the computational training adaptive learning system including game strategy design, while the non-game group is required to use the computational training adaptive learning system without game strategy design. The learning stage is the process of students' self-regulating learning. In the stage of data collection and analysis, the experimental data are collected, sorted out and analyzed, and the experimental results are obtained.

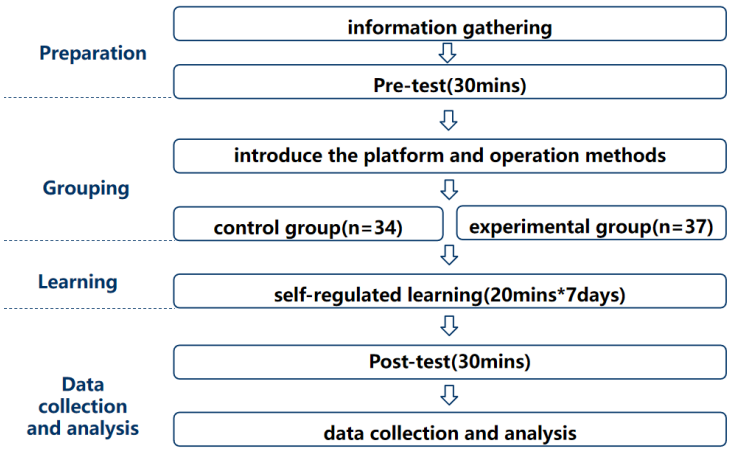

Figure 1: Experimental Flow Graph.

2.2. Adaptive Learning Platform

Adaptive learning platform contains four interfaces, which are the home, computational training, lucky draw and knacks. The four interfaces are shown in Figure 2. Among them, the interfaces of lucky draw and knacks are not open to the non-game group.

The home of the platform mainly presents the gamified background story, aiming to provide students with a learning task distribution context, which is more interesting than directly distributing learning tasks to students. After entering the interface of computational training, the interface will provide computing exercise function service for students. The system will generate mathematical computation training questions, students could put their computation results into the answer area. Then, the system will judge whether it is right or wrong, and give relevant feedback. Moreover, the system would adjust the difficulty of the training questions in real time according to the learning performance of the students.

As for the gamified adaptive learning platform, the computational training interface includes a virtual tutor (elfin) that will provide feedback and emotional regulation based on the students learning

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performance during the learning process. For example, if the students successfully solve the problem, the elfin will smile and issue a "good job" and other positive words of encouragement; If the student has difficulties to solve the problem, the elfin will issue comforting statements such as "All right" "Try again". At the same time, according to the emotional color theory and the environmental color function theory, the background color of the website will change with the students learning behavior and learning results. For example, when the student answers the question correctly continuously, the background of the website will turn purple. Purple is a stimulating and pleasant color, which is used for emotional regulation and learning motivation. If the learner makes a mistake in solving the problem, the surrounding background color will turn red, which serves as a warning and awakens the student's attention.In addition, when students click the achievement manual in the computational training interface, the achievement interface will pop up. The achievement interface, which is shown in Figure 3, contains the periodic achievements and honorary titles that students have obtained. In the meanwhile, the ranking list of the correct rate of doing questions, shows the top ten students in learning performance and the number of questions they have done. Therefore, students can self-motivate and improve their learning motivation through the achievement interface.These features are not available in non-gamified adaptive learning platform.

The lucky draw interface can convert the scores, which are obtained from the phased learning results by the students, into actual rewards through the lucky draw mechanism, in order to stimulate the students' learning motivation and learning interest. The knacks interface mainly provides learners with strategies to improve their computing ability through the virtual tutor. It including quick estimation strategies, verbal calculation strategies and the introduction and application examples of mathematical operation laws.

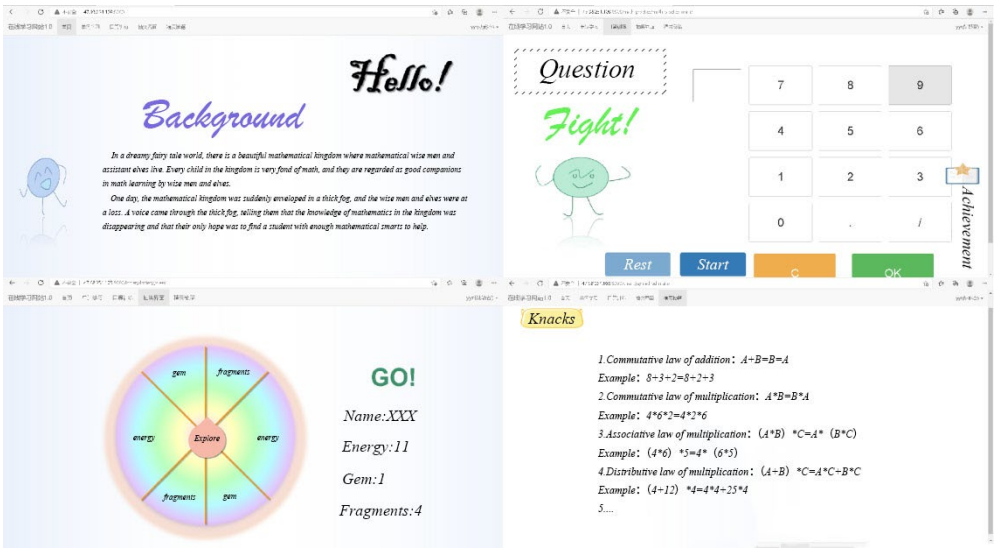

Figure 2: Four functional interfaces of adaptive learning platform.

Figure 3: Achievement interface of gamified adaptive learning platform.

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2.3. Measures

In this study, the Mathematical Computation Test Paper is a self-designed paper containing 25 questions in four dimensions: oral, written, estimation and application of arithmetic.

The Learning Engagement Scale was developed by Tews et al.[8] based on Rich's Engagement Scale and Kahn's Engagement Model. It contains 12 questions on three dimensions: cognition, affect and behavior.

The Cognitive Load Scale is derived from the Cognitive Load Self-Assessment Scale developed by Paas et al.[9], which contains 2 questions and uses a nine-point scoring system.

3. Results

3.1. Learning Time

This section uses independent sample T-test for data analysis and the details are described in Table 1. Through data analysis, it is found that the use of gamified adaptive learning system has a significant effect on students' learning time (p=.006 <.01).

Table 1: Results of the Independent sample T-test for Learning Time.

Learning time	N	Mean	SD	*t*	*df*
Experimental group	37	114.37	52.11	6.77**	69.0
Control group	34	46.87	26.88		

*p＜.05, **p＜.01

3.2. Mathematical Computation

This section uses the linear mixed-effects models to analyze the impact of the gamified adaptive learning system on students' mathematical computation, and the results of the experimental analysis are shown in Table 2. At baseline, there was no statistically significant difference between the measurement scores of the experimental and control groups (p = 0.110). After one week of intervention training, group and time interactions revealed statistically significant changes in measurement scores between the two groups (p = .003 <.01).

Table 2: Results of the Linear mixed model for Mathematical Computation.

Effect	Estimate	SE	95%CI	t	p
(intercept)	21.830	0.295	(21.251,22.409)	73.93	＜.001
Group Effect	0.957	0.591	(-0.200,2.115)	1.62	0.110
Group*Time Effect	-1.907	0.616	(-3.115,-0.699)	-3.09	0.003

*p＜.05, **p＜.01

3.3. Engagement

The experiment uses independent sample T-test to analyze the influence of gamified adaptive learning system on students' learning engagement. The analysis results are shown in the Table 3 below. From the Table 3, it can be found that gamified adaptive learning system has a significant effect on students' learning engagement (p=.03 <.05).

Table 3: Results of the Independent sample T-test for Engagement.

Engagement	N	Mean	SD	*t*	*df*
Experimental group	37	50.8	5.83	2.22*	69.0
Control group	34	46.9	8.98		

*p＜.05, **p＜.01

3.4. Cognitive Load

According to the analysis results of the independent sample T-test, there is no significant effect on students' cognitive load (p=0.965). The analysis results are shown in Table 4. This helps us understand

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that game strategy design for adaptive learning systems does not impose extra cognitive load on the student learning process, which will benefit the student learning experience.

Table 4: Results of the Independent sample T-test for Cognitive Load.

Cognitive load	N	Mean	SD	*t*	*df*
Experimental group	37	13.7	2.73	0.04	69.0
Control group	34	13.7	2.28		

*p＜.05, **p＜.01

4. Discussion

Through the experiment, this study found that the incorporation of gamification strategies was able to significantly increase the time of learning and the number of questions done by the learners, with some learners even actively logging into the system after class for computational training. Perhaps because of these reasons, the improvement of mathematical computation was significantly higher in the experimental group than in the control group; During the learning process, students in the experimental group were more engaged in learning than in the control group, which suggesting that the gamification intervention could make students invest more time and effort in the adaptive learning system and help support their learning more. However, in this experiment, there was no significant difference in the cognitive load between the experimental and control groups of students. In this regard, this study suggests that this phenomenon is due to the adaptive learning system's ability to provide adaptive learning resources, learning environments and learning feedback based on the learner's learning situation, which allows each individual student to be in a good mental state for learning at all times.

5. Conclusion

This research studies the effects of integrating gamification into an adaptive learning system on students' learning performance and experiences. The experimental study found that the adaptive learning system with gamification had a significant positive impact on learners' learning performance in terms of time of learning, number of questions done and engagement in learning, and was effective in supporting students' learning process and helping them to achieve better learning performance and experiences.

In considering the results, however, limitations should be noted. Firstly, the time span of the experiment only lasted for one week due to objective circumstances and space constraints. Secondly, there are still some improvements need to be made to the gamified adaptive learning platform. In addition, due to the limitations of the experimental conditions, there are still some elements of learner characteristics that have not been investigated in depth. Future research will improve the existing platform, and use more scientific techniques to conduct a longer-term, larger-scale experiment to explore the deeper impact of the gamified adaptive learning platform on students.

Acknowledgment

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