

Exploring Personalized Gamified Learning by Computer Software: Enhancing the Effects of Learning-Style Adaptation [†]

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[†] Presented at the 2024 IEEE 4th International Conference on Electronic Communications, Internet of Things and Big Data, Taipei, Taiwan, 19–21 April 2024.

Abstract: The adaptability of learning styles to gamified learning models was explored to better understand the needs and advantages of students in different educational environments. Learning styles reflect the preferences and habits of each student, which are influenced by their upbringing and experienced educational methods. The findings of this study indicate variations in the adaptability of students with different learning styles in gamified learning models. For instance, active, intuitive, and visual learners generally are less suited to solitary learning modes as they prefer interactive and diversified learning approaches. Conversely, these students are better suited to competitive learning modes due to their competitive spirit and desire for challenges. Additionally, reflective, intuitive, intuitive, visual, sequential, and holistic learners are adaptable to collaborative learning modes, with visual learners being particularly adept at learning from others' perspectives. These students enjoy collaborative efforts and tend to achieve better learning outcomes in such environments. Linguistic learners may be less inclined toward gamified learning with graphic user interfaces, as they gravitate toward language and text-based learning methods and have less interest in graphical interfaces. The results of this study underscore the significance of individual learning styles in gamified learning and guide educators and designers to create effective learning environments tailored to students' needs and styles and enhance students' motivation for and effectiveness in learning. This contributes to personalized education to ensure that each student can fully unleash their potential.



Citation: Lai, C.-H.; Lin, C.-Y. Exploring Personalized Gamified Learning by Computer Software: Enhancing the Effects of Learning-Style Adaptation. *Eng. Proc.* **2024**, *74*, 44. <https://doi.org/10.3390/engproc2024074044>

Academic Editors: Shu-Han Liao, Teen-Hang Meen and Cheng-Fu Yang

Published: 2 September 2024



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Keywords: learning style; learning motivation; learning effectiveness; gamified learning model; adaptability

1. Introduction

The operational mode of game-based learning is variable. For instance, in role-playing games, learners engage in the game by assuming one or multiple roles to solve problems or complete tasks in a virtual world according to game objectives [1]. Alternatively, computer simulations of real-life environments and scenarios provide learners with opportunities to grasp concepts. For instance, 'Stop Disasters' employs disaster simulations to help learners recognize the potential risks of natural disasters and learn how to effectively prevent and mitigate their impact on people and the environment [2]. The impact of game-based learning on students can vary depending on the specific game-based learning modes.

Various modes of game-based learning and their impact on student learning achievements and motivation were researched. The game modes encompass 'Single-Player Mode' and 'Multiplayer Mode'. In 'Single-Player Mode', individuals act as the primary agents of the game, unaffected by peers, and complete game objectives based on their performance. For instance, Papastergiou's research on single-player games incorporates memory-related knowledge from computer science courses into the game. This approach allowed learners to acquire course content through problem-solving and gameplay. To enhance the effectiveness of this approach, learners were required to embark on adventures throughout the

game map, defeating monsters to progress to the next learning stage. This adventure-based approach facilitated course reviews and heightened learner interest [3].

The 'Multiplayer Mode' is divided into 'Competition Mode' and 'Collaborative Mode', both of which leverage peer influence as a motivational factor for learners. For example, Burguillo indicated that, over the past decade, the same course had employed different learning activities for competitive learning. The outcomes demonstrated that incorporating competitive elements into the game-based learning system stimulated learners' competitiveness during gameplay. This indicates that motivating students' learning motivation and performance can be achieved through peer competition [4]. Jong et al. integrated game elements with course content, creating online multiplayer cooperative learning games. In the study, students selected roles with different skills and collaborated with peers in teams. The findings revealed that students encountering difficult questions during the game had discussions in small groups or used their character's skills to provide an answer. Even if incorrect responses occurred, they could continue playing. The post-game analysis allowed students to identify the knowledge they lacked and reinforce their understanding. Consequently, the measured learning achievements in the game-based collaborative learning approach were significantly superior to traditional collaborative learning, demonstrating the positive impact of online multiplayer cooperative learning games on student learning effectiveness and their learning journey [5].

While prior research presented the enhanced effects of game-based learning on learning effectiveness, motivation, and even cognitive improvement [6], most studies have focused on specific game modes. There has been limited exploration into which game-based learning mode is appropriate for students. Previous results showed positive effects on students' learning behaviors, and not every student was keen on the game's mode of operation. Given the multitude of factors influencing learning behaviors [7], Chen and Macredie pointed out that key factors influencing learning include prior knowledge, gender, and cognitive style. Their experimental results demonstrated that different factors lead to variations in learning performance, even when the same learning strategy is employed [8,9]. Students' preferences in learning are a significant factor affecting learning effectiveness. Learning preferences were investigated from three dimensions: cognitive style, thinking style, and learning style. Regardless of the specific style, each impacted individual learning outcomes [10].

Based on the previous research, we developed a game-based learning system with three distinct game modes: 'Single-Player Mode', 'Competition mode', and 'Collaborative Mode'. The experimental course focused on 'Operating Systems', with students enrolled in this course as the experimental subjects. These students were grouped based on their learning styles. To compare different game modes and determine the most appropriate game-based learning mode for students, personalized and adaptive learning effects were investigated in this study.

2. Literature Review

2.1. Learning Style

Matching teaching methods to students' learning styles improves students' learning outcomes [11]. Felder and Soloman pointed out that students have their unique learning styles. However, learning styles are not inherently good or bad; they simply reflect how learners acquire information. As a result, learners possess multiple learning styles in their learning process. To enhance students' learning motivation and effectiveness, individual differences must be understood to provide tailored teaching methods that cater to different learning styles. This allows students to acquire knowledge according to their learning habits [12]. Thus, many researchers integrated learning styles into game design and investigated their impact on learning outcomes [13,14]. However, there has been no research analyzing game-based learning modes that suit a learner's learning style. Based on the previous results, we analyzed the compatibility of three game-based learning modes

with students' learning styles to guide students to acquire knowledge during the gaming process and improve learning performance.

2.2. Gamified Learning Model

We categorized various digital game-based learning modes, including the single-player mode and multiplayer mode. The multiplayer mode was divided into competitive and cooperation modes.

1. Single-player mode

When learners lack peer stimulation in this mode, they need to engage in strategic thinking and methods to progress in the game. The process of investing time and effort generates intrinsic motivation, encouraging learners to strive for the mission's accomplishment or the achievement of stage goals [15]. Even when a game demands more than learners' current abilities, such as continuous training to overcome challenges, learners stick to their desire for achievement [16]. Therefore, the single-player mode in digital game-based learning enhances learners' motivation and willingness to learn independently. Repetitive practice and strategy adjustments improve learning outcomes. However, the absence of peer influence in the single-player mode leads to negative effects if the game design fails to stimulate learner motivation or lacks proper guidance. These negative effects include diverting learners' attention from learning to the game or confusing the simulation of virtual-world scenarios with real-life situations, neglecting the prerequisite of establishing the virtual environment. Therefore, the investigation of learning styles for learners in the single-player mode is important.

2. Competition mode

The digital game-based learning mode with competition enhances learning motivation [17] and promotes learning and focusing [18]. The effectiveness of the competition mode in digital game-based learning, in terms of improving learning performance, stems from establishing activity norms within this mode. Students can compete with each other within established rules to achieve goals and learn knowledge through the competitive process, which improves learning effectiveness [19,20] and encourages learners to outperform their peers due to their desire for winning or rewards. However, competitive learning has drawbacks. For instance, if learners become overly fixated on the competition, they may overlook the essence of learning [21]. In addition, competitive learning uses rankings, levels, glory, or victory as indicators of success, which leads to negative emotions, such as frustration or disappointment, especially for learners to compete. These negative emotions impact the overall learning experience. Therefore, as most studies support competitive learning to enhance learning motivation and improve learning outcomes, competition may not be appropriate for every learner. Thus, we explored which types of learning styles suit competitive learning.

Cooperative learning enables learners to construct knowledge through group discussions [22]. With the integration of information technology and cooperative learning, computer-assisted cooperative learning allows learners to overcome time and location constraints. Even when learners are in different places at different times, they can engage in collaborative activities, such as group discussions or practice exercises [23]. In Popov's study, students from different cultural backgrounds were grouped, and their perspectives on cooperative learning were investigated. The results showed that students with individualistic cultural backgrounds had more negative views of cooperative learning, suggesting that learners with a strong sense of individualism were not appropriate for collaborative learning [24]. Therefore, the appropriateness of cooperative learning requires further investigation. Therefore, we analyzed the type of learners for the cooperation mode in game-based learning to provide a personalized game-based learning environment.

3. Experiments

The subjects of this study were 122 students taking an operating system course majoring in information engineering. The students were grouped according to their learning styles. The learning-style questionnaire of the Felder–Soloman Learning Style Test was used in this study [25]. The questionnaire consists of 44 questions in 4 sets, with each set of two opposing types. Each question has two options, ‘a’ and ‘b’, representing the two opposing types. The experimental material was the content of the operating system course, which was divided into 8 concepts and assessed in three different game stages. Before the experiment, the students filled out questionnaires for motivation and learning style. The questionnaire for motivation was used for collecting pre-test data. Based on the questionnaire results, students were categorized into different style groups for an exploration of the effects of diverse game-based learning modes with different learning styles. The experiment consisted of three stages, each involving a different game-based learning mode. Each stage lasted for two weeks, and the entire experiment spanned six weeks. At the end of each stage, student performance was assessed using tests, and system usage data were collected. After completing all three stages of the experiment, students filled out a motivation questionnaire as post-test data.

Three types of game-based learning modes (single-player, competition, and cooperation) were tested. In the gameplay, the students were instructed on island adventures (Figure 1). Players can increase the mission completion rate of the islands by defeating monsters (answering questions). There are six islands: Flame Island, Desert Island, Ghost House, Starlight Tower, Forest Island, and Whale Cave. To distinguish each student who logs into the system, all the students, regardless of the game-based learning mode, registered before logging into the system with a student ID and password. The system used this registration information to identify students’ performance in different game-based learning modes. Additionally, to allow students to track their learning progress, personal information was added to the system to view their current game progress and understand their learning situation. Teachers monitored students’ progress through game-based learning activities.



Figure 1. Interface of the game in this study.

3.1. Single-Player Mode

The single-player mode is designed with a mission-oriented approach, allowing students to explore the islands and complete the course content. When a student enters an island in the single-player mode, the system presents the game's storyline and provides relevant system operation instructions, such as the game's opening narrative. After reviewing the story content and system instructions, the student can begin the game. The adventure mode varies depending on the platform the player is using: shaking the phone or continuous mouse clicks. When the system detects that the student is shaking the phone or clicking continuously, it randomly generates questions, indicating an encounter with a monster. At this point, the student must answer the questions presented by the system. The results of these answers not only represent the student's familiarity with the topic, but also determine the rewards and penalties within the game. If a student answers a question correctly, they receive new equipment or items, while incorrect answers result in a reduction in the in-game character's health points. Due to the presence of many monsters (questions) on each island, the system randomly selects a monster (question) for students to battle (answer) when they enter an island. The questions are designed as multiple-choice questions, and students must reach a specified threshold for defeating the monsters on the island to consider the adventure completed. A successful battle indicates that the student's familiarity with the chapter has reached the system's predefined threshold. As each island is populated with a variety of monsters (questions), students entering an island engage in battles (answering questions) with these randomly selected monsters (questions).

The questions were created as multiple-choice questions, and students were required to reach a system-defined threshold for defeating the island's monsters to complete the adventure. If a student succeeds, the student reaches the level of familiarity with the content specified by the system for that chapter. To address the concerns of large quantities and prolonged answering times potentially causing student fatigue, we employed the Sequential Probability Ratio Test (SPRT) for threshold detection. To reduce the response time and the number of questions, the SPRT+ testing approach was used [26]. This method selects a probability model with high confidence. Recognizing that high confidence does not rely on students' self-assessment; the probability of answering correctly for unfamiliar concepts (P_n) is reduced from 0.75 to 0.6 in SPRT++ [27]. This means that, for each island adventure challenge, the system randomly generates ten monsters (questions). A student needs to complete the challenge by answering four questions correctly in a row, while continuous incorrect answers to four questions in a row result in challenge failure. Additionally, answering seven out of nine questions correctly is regarded as a successful challenge.

Because the single-player mode developed in this study was designed for students to complete independently, the students rely on themselves to pass each level in the game. They cannot have assistance from peers or other external support to complete these challenges. Within this framework, the impact on students with different learning styles was explored in this research to analyze the learning styles for the single-player mode in game-based learning.

3.2. Competition Mode

Based on the differentiation of various game-based learning modes using islands in the system development, students can choose the corresponding island to engage in the competition mode of game-based learning. Previous research results showed that competitive learning has positive effects on students, and incorporating competitive elements into game-based learning increases students' motivation and interest in learning. In many game-based learning studies with competitive elements, leaderboards are commonly used. For example, Hwang developed a competitive game-based learning system with a chessboard as the central theme, where players advanced a certain number of steps by rolling dice and encountered corresponding game tasks at each location. Solving these tasks earned them points. He incorporated leaderboards as a competitive element, allowing students to check their current rankings. The results of this study showed that such a

competitive element improved students' learning attitudes and enhanced their interest in learning. Considering that an excessive number of competitive elements can complicate subsequent analysis in identifying specific sources of impact, the competition mode in this study adopted a leaderboard mechanism.

When students enter an island belonging to the competition mode, they can participate in island adventures similar to those in the single-player mode. They accumulate correct answers by attacking monsters (answering questions) and can check their current scores and peer rankings through the player leaderboard. This real-time leaderboard stimulates sound competition among peers. Since the course chapters corresponding to the single-player mode and competition mode are different, the progress and achievements accumulated by the students in the single-player mode are not carried over. In other words, students need to accumulate correct answers again when they switch to the competition mode, and the leaderboard in the competition mode presents activities within that mode as the basis for ranking.

3.3. Cooperation Mode

The cooperation mode is differentiated by islands in the game-based learning system. Students can choose the corresponding island for cooperative game-based learning. In the cooperation mode, when students enter an island, a level list is displayed. Each level accommodates up to 3 students. When a student chooses to enter any level, they see other students at the level. Students can view each other's equipment and status. If a student is ready to proceed, they can press the option to prepare for battle. When a student presses the ready-for-battle option, their status changes to ready. When three students in that level are ready for battle, they enter the question-answering screen. Each student takes turns to answer questions and attack monsters. When the monster's health reaches zero, they win. If there are errors in the answering process, students experience monster attacks, reducing the team's health. When the team's health reaches zero, the challenge fails. In the cooperation mode, the number of correct answers and question difficulty must be higher than in the competition mode. When students have questions at various levels, they can increase their chances of completing the challenge by discussing the questions with their team members in discussion.

4. Results and Discussion

4.1. Learning Motivation

To explore the changes in the learning motivation of students of different learning styles, we conducted a pre-test and post-test using an in-group one-way ANOVA test (Table 1). Except for linguistic learners, students with other learning styles improved their learning motivation after the experiment. F-values did not exceed the threshold, indicating that the increase in learning motivation did not have statistical significance. Though game-based learning employed a graphical user interface for visual effects, this design was less appealing to linguistic learners who preferred text and verbal modes. They may not be attracted to the visually oriented learning approach as students with other learning styles. Therefore, we observed a decrease in learning motivation among linguistic learners in the post-test.

Table 1. ANOVA test results of learning motivation for students with different learning styles pre-test and post-test.

Learning Style	Stage	N	Mean	Standard Deviation	F	Threshold
Active	Pre	12	154.083	28.659	0.389	4.301
	Post	12	160.75	23.661		
Reflective	Pre	17	159.941	33.346	0.071	4.149
	Post	17	162.588	23.529		

Table 1. Cont.

Learning Style	Stage	N	Mean	Standard Deviation	F	Threshold
Sensing	Pre	21	154.857	12.444	0.135	4.085
	Post	21	158	12.570		
Intuitive	Pre	17	167.941	12.959	0.001	4.149
	Post	17	168.235	12.971		
Visual	Pre	61	155	23.776	3.76	3.92
	Post	61	162.885	21.060		
Verbal	Pre	4	172.75	52.449	0.072	5.987
	Post	4	163.75	41.788		
Sequential	Pre	10	162.6	33.738	0.227	4.414
	Post	10	168.9	24.718		
Global	Pre	21	166.238	26.717	0.152	4.085
	Post	21	169.143	21.256		

The α value is 0.05.

4.2. Learning Achievement

To understand the extent to which students with different learning styles exhibit noticeable improvements in learning achievements in various game modes, inter-group one-way ANOVA was used to analyze learning achievements before and after the experiment for each learning-style group. The results indicate the differences in learning achievements with different learning styles in different learning modes. Active learners showed significant improvements in learning achievements in the single-player and competition modes, but no significant difference was observed in the cooperation mode. Active learners performed better in competition modes, as they enjoyed challenges and competition, which stimulated their learning motivation. Reflective learners exhibited better learning achievements in the cooperation mode, whereas their performance was normal in the single-player and competition modes. Reflective learners preferred learning from other's perspectives in the cooperation mode. Intuitive learners performed well in competitive and cooperation modes, but showed less improvement in the single-player mode, indicating that intuitive learners enjoy challenging and interactive learning methods. Sensory learners demonstrated learning achievements in both competitive and cooperation modes, but their performance was less impressive in the single-player mode. Sensory learners preferred challenges and interactions. Visual learners achieved better learning outcomes in both competitive and cooperation modes, but performed less effectively in the single-player mode. Visual learners may require more visual stimuli to enhance their learning motivation.

Students with different learning styles exhibited various adaptability to different game-based learning modes. Active, intuitive, and visual learners were not suited to the single-player mode. The ANOVA results show a significant decline in these learning styles. While the students were interested in individual learning, they were inclined toward competitive and cooperation modes, which need more interaction and challenges and stimulate their learning motivation. Active, intuitive, reflective, visual, sequential, and global learners were well-suited to the competition mode. The ANOVA test results for learning achievements before and after the competition mode show significant improvements. The students performed better in competition modes because they enjoyed challenges and competition and enhanced their learning motivation.

Reflective, intuitive, sensory, visual, sequential, and global learners were well-suited to the cooperation mode, with visual learners particularly excelling in this mode. The ANOVA test results show a significant improvement for the students. Visual learners exhibited higher adaptability to the cooperation mode, possibly because they preferred teamwork and learning from others' perspectives. Verbal learners were less suited to game-based learning

with a graphical user interface. These students were less interested in graphical interface game-based learning without significant improvement. In the experiment, the graphical interface was a challenge for verbal learners, who tended to learn through language and text-based learning. Active learners were not appropriate for the single-player mode but for the competition mode. Reflective learners were good at the cooperation mode, and they did not prefer the single-player mode, though their performance was acceptable. Active learners exhibited a significant decline in the single-player mode but improved in the competition mode, indicating they were better fitted to the competition mode. Reflective learners achieved better learning outcomes in the cooperation mode, and despite their lower preference for the single-player mode, their performance in this mode was acceptable.

5. Conclusions

We explored the adaptability of students with different learning styles in different learning modes in a game-based learning environment. Through the analysis of the experimental results, the following conclusions were obtained.

There were differences in the adaptability of students to different learning styles in the game-based learning modes. Active, intuitive, and visual learners were not good at the single-player mode. These students decreased their learning achievements in the single-player mode, possibly because they were inclined toward competition and cooperation for interaction and challenges. Therefore, in the design of game-based learning courses, educators must avoid the application of a single mode for students of various learning styles. Active, intuitive, reflective, visual, sequential, and global learners were good in the competition mode. These students improved their learning achievements in the competition mode, indicating their higher demand for challenges and competition. The competition mode stimulated their learning motivation and motivated them to engage in learning. Therefore, when designing competitive game courses, integrating elements of different learning styles must be considered to attract a broader range of students. Reflective, intuitive, sensory, visual, sequential, and global learners were good in the cooperation mode, with visual learners being adaptable to this mode. These students improved their learning achievements in the cooperation mode because they preferred teamwork and learning from others' perspectives. The cooperation mode cultivated students' collaborative abilities and provided a conducive environment for knowledge-sharing. Therefore, in the design of cooperative game courses, we must consider how to guide students to collaborate better, especially visual learners. Verbal learners were less appropriate for game-based learning with a graphical user interface. These students were less interested in graphical interface game-based learning, and there was no significant improvement observed in the learning achievements. They were challenged and preferred language and text-based learning. Therefore, it is necessary to provide diverse interface options to meet the needs of students with different learning styles.

The results of this study underscore the importance of learning styles in game-based learning modes and provide the basis for the design of personalized learning environments. The results contribute to enhancing students' learning motivation and achievements and can be used for the development of education. Personalized education is the future of education as it ensures that every student realizes their potential in game-based learning. The needs of students with different learning styles need to be understood to offer adaptive learning environments for innovation in education.

Author Contributions: Conceptualization, C.-H.L.; methodology, C.-H.L.; software, C.-Y.L.; validation, C.-H.L.; resources, C.-H.L.; data curation, C.-H.L.; writing—original draft preparation, C.-H.L.; writing—review and editing, C.-H.L.; visualization, C.-H.L.; supervision, C.-H.L. and C.-Y.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are not available due to school privacy policies.

Conflicts of Interest: The authors declare no conflicts of interest.

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