Serious Video Game to Improve the Learning of Software Design Patterns

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Abstract **– The primary aim of this study conducted in 2023 was to enhance the understanding of software design patterns at a private university in Trujillo. Utilizing an applied, purely experimental design, the research involved 60 fourth-semester students from the systems engineering program, divided equally into a control group (CG) and an experimental group (EG). The latter group engaged with a serious video game as part of the learning process. Data collection was facilitated through questionnaires and observation, and analyzed using Jamovi software version 2.4.11. Findings indicated notable improvements: a 5-point increase (25%) in knowledge retention (LKR), a 1-point rise (5%) in understanding (LU), a 0.46-point growth (9.2%) in motivation (LM), and a 0.50-point boost (10%) in satisfaction (LS). The study concluded that integrating a serious video game significantly bolstered the learning of software design patterns at the institution.**

Keywords **– Serious video game, learning, SUM methodology, software design patterns, academic software.**

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1. Introduction

In 2023, due to the impact of the COVID-19 pandemic, the software industry gained increased significance, highlighting the need for sustainable software development practices. Soto-Duran *et al.* [1] emphasized the importance of adhering to good practices in software development to yield a high-quality product. One of these crucial practices involves the utilization of software design patterns. According to González *et al.* [2], the proper application of design patterns results in the creation of well-structured, maintainable, and reusable software.

Ferrandis [3], from the Polytechnic University of Valencia, highlighted that design patterns provide solutions to common programming problems. Each design pattern has been proposed by specialists with extensive experience in addressing prevalent programming challenges, offering comprehensive solutions to these issues. Conversely, when inappropriate solutions are applied, it can lead to numerous difficulties that directly impact code maintenance.

The problems caused by not implementing design patterns not only affect the software, but also negatively affect the company in charge of the development. Mentioned that the lack of knowledge about design patterns is a frequent inconvenience for software developers, causing the same developer to reformulate the implementation that is being applied, which negatively influences both the time and the development costs for the company.

González *et al.* [2], created a game to enhance software engineering students' understanding of software design patterns. The research employed a quantitative methodology with a strictly experimental design. Participants were computer engineering students at the Colombian Polytechnic Jaime Izasa Cadavid, who were between their 5th and 6th semesters and aged 18 to 28. These participants were organized into five groups of three to six members each, with an additional eight students playing the game on their own.

Information was gathered using survey methods. Initial results indicated that prior to playing the game, about 45% of these students possessed preliminary knowledge of design patterns. However, after using the game, 100% of the students were able to identify and name a minimum of 3 design patterns. One significant conclusion drawn from the study was that, due to the game being in English, students working in groups were unable to progress beyond 41% completion in approximately 75 minutes. In contrast, students who played individually completed 100% of the game in approximately 100 minutes. This provided valuable insights into knowledge retention levels as a key indicator. In the private university in Trujillo, students in the Systems Engineering program were found to learn about software design patterns in a rather superficial manner. Given this observation, it becomes evident that there is a need to enhance the quality of instruction in this important area of software development. Students should receive more comprehensive and in-depth training in software design patterns to better prepare them for the challenges of real-world software development projects. This research has highlighted the potential of serious video games as a tool for achieving this goal and improving the overall learning experience for students in the systems engineering program.

Based on the information presented above, the decision was made to employ a serious video game as a means to enhance the learning of software design patterns. Serious video games are particularly suited for teaching new knowledge to users, as they focus on educational content. As Zhu *et al.* [5] pointed out, serious games find applications in various fields such as education, training, and healthcare. Serious games integrate educational theories and motivational strategies to actively involve learners in ways that are notably different from conventional teaching methods. These games are recognized as an effective recourse that helps to acquire new knowledge.

Considering the potential benefits of engaging teaching methods, the research question posed was: how the implementation of a serious video game could affect software design pattern learning at a Private University in Trujillo in the year 2023. The issues addressed included the effects of such a game on knowledge retention, understanding, motivation, and satisfaction with learning software design patterns at the institution. The main goal of this study was to enhance the comprehension of software design patterns among students by utilizing a serious video game at a private university in Trujillo during 2023.

Objectives included boosting knowledge retention, understanding, motivation, and learner satisfaction. The hypothesis posited was that employing a serious video game significantly enhances the learning outcomes for systems engineering students at this university. Specifically, it was hypothesized that the game would: (a) improve retention of knowledge about software design patterns, (b) deepen understanding of these patterns, (c) enhance student motivation, and (d) increase student satisfaction with their learning experiences.

In this study, the hypothesis proposed that utilizing a serious video game significantly enhances the learning of software design patterns among systems engineering students at a private university in Trujillo in 2023. The hypotheses were specified as follows: (a) using a serious video game boosts knowledge retention concerning software design patterns at the university, (b) it enhances understanding of software design patterns, (c) It elevates motivation levels related to learning software design patterns, and (d) it increases satisfaction with the learning experience of software design patterns at the university during 2023.

2. Related Works

This section introduces key research studies that form the foundation for this investigation. It highlights the impact of ICT-based methodologies and gamification on learning outcomes in programming courses. The discussion encompasses various metrics such as knowledge retention, understanding, motivation, and satisfaction. By examining these studies, the analysis situates the current research within the broader context of existing literature and underscores the significance of these educational strategies in enhancing student performance and engagement.

Beltrán's thesis [6] aimed to outline a methodological proposal for executing autonomous work based on the development of ICT. The study focused on its influence on student motivation and academic performance in the subject programming I. The research involved a sample of 2,858 students and utilized surveys and observation for data collection. The main results were that 100% of those surveyed expressed a very high degree of motivation for the programming I course, 70% expressed that they improved their level of knowledge about programming in the course and almost 100% expressed a level of satisfaction between satisfactory and very satisfactory with respect to their learning.

The main conclusion was that the implementation of gamification strategies in a virtual learning platform influenced the students' motivation and contributed to obtain better grades, increasing their academic performance. As a contribution, this background provided results on the indicator of knowledge retention level, motivation level and satisfaction level. Jaimez-González [7] wrote an article that focuses on enhancing the instruction and acquisition of web programming skills at the Universidad Autónoma Metropolitana, specifically within the LTSI's dynamic web programming courses. It involved a group of 22 students—18 males and 4 females—using surveys for data collection. The findings indicated that over 90% of the participants found the educational materials effective in aiding their understanding, reinforcement, and learning of the course content. The conclusion highlighted that both the web portal and its instructional materials were deemed highly suitable. This research contributed valuable insights to define the comprehension level indicator.

The thesis carried out by Santillana [8] aimed to enhance the educational motivation of fifth-semester students enrolled in the programming course within the computer science department at a higher education institute in Arequipa, had a sample of 9 students and used the questionnaire as an instrument for data collection. The main results were that 65% of the application questionnaires and 100% of the assignments were completed with a satisfactory grade with averages of 16.9 and 19.6 respectively and that 57.1% of the students stated that they "totally agreed" that the application of gamification, through the LMS Moodle, increased motivation with respect to learning the course and there was no evidence of a percentage expressing that the students "disagreed" or "totally disagreed". The main conclusion was that the application of gamification used in the methodology of the Programming Languages III course increased motivation with respect to learning. As a contribution, this background provided results on the motivation level indicator.

The article by Aedo *et al*. [9] aimed to present the experience on teaching the fundamentals of object-oriented programming based on the application of a geolocalized video game. The study involved 60 students from the School of Systems Engineering at Universidad de San Agustín de Arequipa. The study was structured into two distinct groups: a control group and an experimental group, with each group comprising 30 students. Data collection was conducted through questionnaires and evaluations of the learning unit. The main results obtained were that, in the control group, 66.67% of the students passed with an average of 12.25 in vigesimal grade, while in the experimental group, 90% of the students passed with an average of 14.78 in vigesimal grade. The main conclusion was that it was demonstrated that the teaching of object-oriented programming concepts, bolstered by a geolocalized video game, yielded improved outcomes. This approach contributed insights into the levels of knowledge retention indicator.

3. Methodology

This section outlines the methodologies used to investigate the variables of learning serious video games, along with the software development methodology employed for creating the video game.

3.1. Learning

With respect to learning, the dependent variable, Díaz [10] mentioned that it is constituted by a set of psychological and biological processes that occur in the cerebral cortex. These processes guide individuals to change their abilities, attitudes, and knowledge as a result of experiences acquired through contact with the environment, aiming to provide adequate answers to specific questions. Also, Estrada [11] mentioned that, it is a process through which knowledge of both formative and informative type is obtained. Likewise, Sanchez [12] mentioned that, it is like the transformation that occurs, maintaining certain stability, in the behaviour of a person. The person who acquires knowledge experiences a change when moving from one situation to another, thus achieving a modification in his or her behaviour. To measure learning, the following indicators were used: level of knowledge retention (LKR), level of understanding (LU), level of motivation (LM) and level of satisfaction (LS).

The following indicators were used to measure learning: level of knowledge retention, level of understanding, level of motivation, and level of satisfaction.

The first indicator is the level of knowledge retention, which according to Aparicio *et al.* [13], is an interpretative process based on the learner's skills and the conviction that there is knowledge that is more valid than others, which can be acquired more faithfully according to the techniques used by the learner, such as continuous review. Likewise, Garcés [14] mentioned that, it is an important pillar within the construction of knowledge assets so that it can be reused later, either as explicit or tacit knowledge. The latter is particularly significant when there are few social actors who possess it, as its loss could have negative consequences.

The second indicator this level of understanding, which according to Ocampo [15], is the ability to think and act flexibly using what is already known, implies having the capacity to obtain knowledge and apply it in diverse contexts as needed, it consists of a conclusive cognitive process, modulating a generative knowledge. Likewise, Cedeño *et al.* [16] mentioned that understanding enables the effective and efficient expression of acquired knowledge, facilitating the incorporation of methodologies and strategies that promote the transfer of knowledge.

The third indicator is the level of motivation, which according to Méndez *et al*. [17], school motivation is defined as an intrinsic change in the student that spurs and governs their behavior to learn and achieve their proposed objectives in the classroom, either by the need to inquire, curiosity to learn, to achieve a pleasing grade or the fear of failing a subject. López and Sánchez [18] mentioned that, motivation is an internal process that can be influenced by various personal factors, such as academic goals, self-sufficiency or directly linked to personal achievement.

As a fourth indicator this level of satisfaction, which according to Méndez *et al*. [17], it is inevitable to contemplate satisfaction in the learning service as one of the main columns in the realization of educational teaching and that this causes complacency within the student's mind, conceptualizing knowledge, learning and teaching, causing an academic increase in a quantitative as well as qualitative way. Likewise, Arras *et al*. [19] mentioned that, several elements in a person's environment influence the satisfaction he/she experiences, such as positive results and expected responses, generating confidence in the one who experiences it.

3.2. Serious Video Game

Regarding serious video game, independent variable, Paredes-Otero [20] mentioned that it is a simulation of reality itself, in which a fictitious scenario is developed from a real problem and it is here where the player has a role in the situation and has the objective of providing a solution to it. The variables can be changed and all possible scenarios can be evaluated, omitting the possible damage in real life. Also, Guerra [21] mentioned that, these video games have been designed with the intention of allowing the player to simulate skills or abilities in a virtual environment with the purpose of applying them in real situations. Their main objective is to train the player to acquire specific skills, abilities, or knowledge. Massa and Bacino [22] mentioned that, serious games encourage us to reconnect with our primary function of learning, prompting us to use them in a professional manner to contribute value to society.

Aguilar *et al.* [23] mentioned that, serious video games can be classified according to their purpose, among which are: Advergame, is used in the promotion of both products and services with the purpose of positioning the product in an eye-catching environment within the game; Edutainment, has as its purpose an educational purpose that by joining the conventional purpose of games to entertain provides the user with an attractive learning environment with elements which favor the learning process; Edumarket, is a serious game that unites aspects of advergaming and edutaiment, with the objective of transmitting information and simulation games, whose purpose is for the user to exercise skills and behaviors.

3.3. SUM Methodology

With respect to the software development methodology, in the present research the SUM methodology was used for the development of the video game, according to Acerenza *et al*. [24], This methodology primarily aims to create high-quality video games efficiently and cost-effectively, while continuously enhancing the process to boost both efficiency and effectiveness. As Chero [25] noted, the SUM methodology, tailored specifically for video game development, adapts its structure and roles based on Scrum principles. It targets small, cross-functional teams of two to seven people and short-term projects that last no longer than a year. The goal is to deliver predictable outcomes, effectively manage project resources and risks, and optimize the productivity of the team. One of the key strengths of SUM is its flexibility and ability to integrate with other methodologies.

4. Methodology

This section outlines the methodologies used to investigate the variables of learning and serious video games, along with the software development methodology employed for creating the video game.

This investigation falls under the category of applied research. Esteban [4] defines applied research as focused on addressing practical problems in the distribution, production, and consumption of services and goods in various areas of human activity. It builds on the principles of basic or fundamental research, rooted in formal or empirical sciences. The objective is to create hypotheses or research questions designed to address challenges that impact the welfare of society.

The target population for this study encompassed all students enrolled in the systems engineering program at private universities worldwide. Given the vast and dynamic nature of this population, it was not feasible to establish an exact count of the total number of students.

For this study, 60 fourth-semester systems engineering students from a private university in Trujillo were chosen in 2023. The students were split into two groups of 30: one control group and one experimental group. A serious video game was utilized in the descriptive analysis to improve learning about software design patterns at the university. The experimental group used this game for 30 days to potentially influence various performance indicators. After this period, both groups were evaluated to measure the impact of the game on factors such as knowledge retention (LKR), understanding (LU), motivation (LM), and satisfaction (LS). The results were organized and displayed using tables and histograms for each indicator.

Following the experimental phase, the data collected from the post-test after using the serious video game were analysed for normality to check if they followed a normal distribution. The Shapiro-Wilk test, ideal for smaller samples such as the control and experimental groups which each had 30 students, was used for this analysis. The tests were conducted using the Jamovi software, version 2.4.11. Based on the data distribution, appropriate statistical tests were chosen: the T-Student test for parametric data and the Mann-Whitney U test for non-parametric data, to either support or refute the hypotheses related to each performance indicator.

The SUM methodology, as outlined by Acerenza *et al.* [1], is designed with the primary objectives of developing high-quality video games within defined timeframes and budget constraints while continuously enhancing the process for improved efficiency and effectiveness. This methodology comprises five distinct phases and incorporates an ongoing process for risk management.

The initial phase, known as the concept phase, involves the creation of a concept document that provides comprehensive details about the video game. This document addresses various aspects, including the game's characteristics, genre, gameplay mechanics, setting, storyline, target audience, and sources of inspiration. Some of the notable characteristics mentioned in this phase include:

- The game is intended to be played on laptop or desktop PCs running the Windows operating system.
- It features three distinct scenarios, each centered around a specific type of design pattern.
- The game will incorporate a first-person player character.

Moving on to the planning phase, a foundational project document is formulated. This document encompasses an in-depth description of the project, its rationale, key stakeholders, quantifiable objectives, requirements, assumptions, and other essential elements. Additionally, the project schedule and budget are outlined within this document.

Table 1. Functional Requirements of the Video Game

Code	Name	Description
RF01	The video game must allow scenario selection.	Players must be able to select one of three scenarios: Creative, Structural and Behavioral.
RF02	The video game must allow exploration of each scenario.	Players should be able to explore each scenario, which consists of two houses (one for information and one for questionnaires) and interact with them.
RF03	The video game should display information about the patterns.	In the information house of each scenario, players can access informative material about the design patterns of the selected type. For each pattern there should be its function, applicability and an example class diagram.
RF04	The video game should display quizzes about the pattern types.	In the quiz house of each scenario, players can answer questions about the design patterns of the selected type.
RF05	The video game should display the score of the solved quiz.	Players will be able to display their score at the end of each quiz with a message depending on their score.

Table 1 outlines the functional requirements of the video game. During the elaboration phase, the development team focused on designing the interfaces that are integral to the video game, using iterative processes to ensure full functionality and seamless operation.

As shown in Figure 1, the environment was designed for each level of the video game, which consisted mainly of 2 houses, where the first was the Information House, where the player had the option of consulting the information of the selected pattern, and the second was the Question House, where the player faced questionnaires about the respective patterns of the level.

Figure 1. Environment design by level

As shown in Figure 2, the Information House interface was designed, in which the player can access the function, the applicability and an example of a class diagram according to the selected pattern.

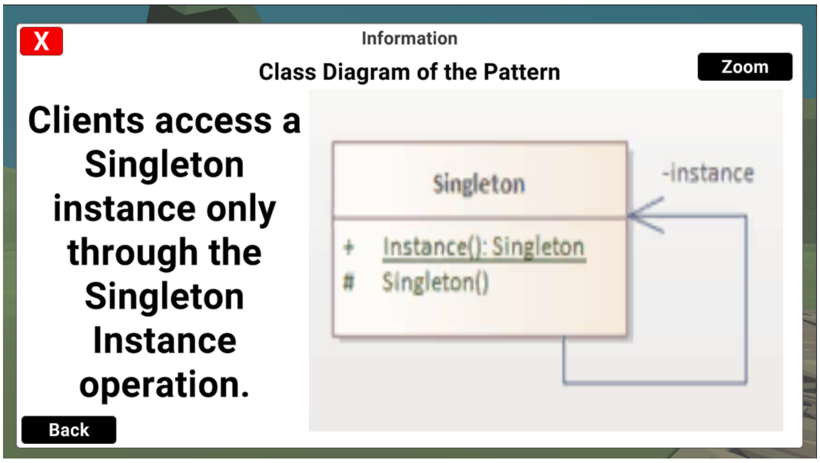

Figure 2. Information house content

As shown in Figure 3, the interface of the House of Questions was designed, in which the player will face a questionnaire with 5 random questions, which are about the patterns according to the selected level.

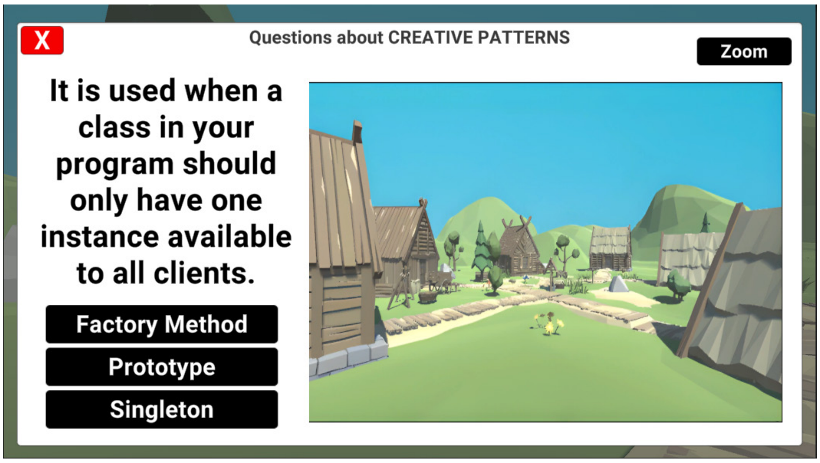

Figure 3. House of Questions content

As shown in Figure 4, the code corresponds to the House of Questions, it is shown how the information of the question is loaded as the player answers the questionnaire, as well as the handling in case there are no more questions to answer.

```
private void ShowQuestion()
{
    if (currentQuestionIndex < questions.Count)
    {
        QuestionDto currentQuestion = questions[currentQuestionIndex];

        if (!string.IsNullOrEmpty(currentQuestion.image))
        {
            StartCoroutine(LoadImage(currentQuestion.image));
        }

        textQuestion.text = currentQuestion.text;
        List<AlternativeDto> alternatives = currentQuestion.alternatives;
        RandomAlternatives(alternatives);
        alternative1.GetComponentInChildren<TextMeshProUGUI>().text = currentQuestion.alternatives[0].answer;
        alternative2.GetComponentInChildren<TextMeshProUGUI>().text = currentQuestion.alternatives[1].answer;
        alternative3.GetComponentInChildren<TextMeshProUGUI>().text = currentQuestion.alternatives[2].answer;
    }
    else
    {
        Restart();
        panelScoreScript.SetRightQuestions(rightQuestions);
        scoreScript.SaveScore(rightQuestions);
        panelQuestion.SetActive(false);
        panelNext.SetActive(true);
    }
}
```

Figure 4. Question visualization code

Next, in the beta phase, the required iterations were carried out to correct the bugs identified in the video game tests. During this process, errors were evaluated and prioritized changes were recorded. Table 2 presents the bugs identified and Table 3 the changes made.

Table 2. Identified errors

ERRORS	
TYPE	**DESCRIPTION**
DESIGN	Videogame panels do not adapt to all devices
	Panel elements moved out of position in some cases

Table 3. Changes

CHANGE LIST	
ITEM	**DESCRIPTION**
1	The panels were configured to adapt to any device.
2	The elements of the panels were configured to be in a fixed space within the panel.

In the closure phase of the SUM methodology, the final version of the video game is published, and a comprehensive review of lessons learned during the development process is conducted. Some of the key takeaways from this phase include:

- When working with Unity, it is crucial to consider the specific version being used for development. Different versions of Unity may have significant differences, making it essential to review the official documentation before selecting a particular version.
- Developing a video game from scratch is a complex undertaking, and it requires additional information and practical experience for more effective development.
- When establishing communication with an API, it is essential to ensure that the URL is secure with SSL, as Unity does not allow requests to unsecured URLs.

Additionally, users can access the executable version of the video game through the provided link: https://acortar.link/houYBs.

5. Results

This section includes both a descriptive and inferential analysis for each indicator to determine whether to reject or accept the hypothesis associated with each. For a comprehensive view of the results, please visit the following link: https://acortar.link/z7kZQa.

5.1. Descriptive Analysis

The results for both control group (CG) and the experimental group (EG), each comprising 30 students, are detailed in the analysis, which includes both quantitative and qualitative measures. For the quantitative aspects, the evaluation calculated the average scores of both groups. Additionally, it assessed several metrics, such as the number of students in the experimental group (EG) who scored above the group average, those who exceeded the set performance target, and the overall achievement levels within the experimental group whose scores were higher than the average of the control group (CG). For qualitative statistics, the following steps were taken: calculation of the frequency of students falling into each distinct level and determination of the percentage representation of each level in relation to the total number of students.

Table 4. Statistical summary of quantitative measurements

Research Indicators	Average GC	Average GE	Goal	N Higher than average			% Higher than average		
				EG	SG	CG	EG	SG	CG
Level of Knowledge Retention (LKR)	9	14	11	15	18	21	50	60	70
Level of Understanding (LU)	7	8	11	17	7	19	56.67	23.33	63.33

In Table 4 of the evaluation results, it is clear that 50% of the (EG) scored above their average in the level of knowledge retention (LKR) during the post-test. Moreover, 60% surpassed the established research target for LKR, and 70% exceeded the Control Group's (CG) average post-test score in LKR.

Similarly, for the level of understanding (LU), 56.67% of the EG's post-test scores were above their average understanding. Furthermore, 23.33% exceeded the goal set by researchers for LU, and 63.33% scored higher than the CG's average in the post-test for LU.

Table 5. Summary statistics for qualitative measurements

Research Indicators	Level	Frequency		Total %		General Average	
		GC	GE	GC	GE	GC	GE
Level of Motivation (LM)	Low	2	0	6.7	0	3.38	3.84
	Neither Low nor High	19	13	63.3	43.3		
	High	8	11	26.7	36.7		
	Very High	1	6	3.3	20.0		
Level of Satisfaction (LS)	Very Low	2	0	6.7	0	3.20	3.70
	Low	10	4	33.3	13.3		
	Neither Low nor High	8	10	26.7	33.3		
	High	7	13	23.3	43.3		
	Very High	3	3	10.0	10.0		

Table 5 in the analysis of level of motivation (LM), it is evident that among the control group, 6.7% exhibited a "Low" level of motivation (LM), while the majority, constituting 63.3%, displayed a "Neither Low Nor High" level of motivation (LM). Furthermore, 26.7% of the control group demonstrated a "High" level of motivation (LM), and a minority of 3.3% exhibited a "Very High" level of motivation (LM). In contrast, among the experimental group, 43.3% displayed a "Neither Low nor High" level of motivation (LM), 36.7% demonstrated a "High" level of motivation (LM), and 20% exhibited a "Very High" level of motivation (LM).

Regarding level of satisfaction (LS), in the control group, 6.7% had a "Very Low" level of satisfaction (LS), 33.3% had a "Low" level of satisfaction (LS), 26.7% had a "Neither Low nor High" level of satisfaction (LS), 23.3% exhibited a "High" level of satisfaction (LS), and 10.0% had a "Very High" level of satisfaction (LS).

On the other hand, in the experimental group, 13.3% displayed a "Low" Level of Satisfaction (LS), 33.3% had a "Neither Low nor High" level of satisfaction (LS), 43.3% demonstrated a "High" level of satisfaction (LS), and 10.0% exhibited a "Very High" level of satisfaction (LS).

5.2. Inferential Analysis

The analysis encompassed two critical components: a normality test and a hypothesis assessment. The normality test was structured around two hypotheses: H0 (Null Hypothesis) suggests that the data follows a normal distribution ($p \geq 0.05$), whereas H1 (Alternative Hypothesis) indicates that the data does not follow a normal distribution ($p < 0.05$). Based on these hypotheses, two decision-making rules were implemented: 1) If $p < 0.05$, the null hypothesis (H0) is rejected in favor of the alternative hypothesis (H1); 2) If $p \geq 0.05$, the null hypothesis (H0) is accepted, and the alternative hypothesis (H1) is rejected.

Table 6. Outcomes of Shapiro-Wilk tests for normality across the indicators

Research Indicator	Control Group (GC)	Experimental Group (GE)
NRC	0.017	0.001
NC	0.06	0.059
NM	0.04	0.239
NS	0.18	0.46

Upon reviewing Table 6, it was determined that the p-value for the normality test of the level of knowledge retention (LKR) for the control group (CG) stood at 0.017, demonstrating that the data were not normally distributed. Similarly, the experimental group (EG) displayed a p-value of 0.001 for the same indicator, confirming a non-normal distribution. Therefore, the nonparametric Mann-Whitney U test was applied to this indicator.

Conversely, the normality test for the level of understanding (LU) in the CG showed a p-value of 0.06, indicating a normal distribution. The EG also showed a similar trend with a p-value of 0.059, confirming normal distribution of data. Hence, the parametric T-Student test was used for this indicator.

For the level of motivation (LM), the CG's p-value was 0.004, indicating non-normal distribution, whereas the EG had a p-value of 0.239, suggesting that the data followed a normal distribution. This led to the selection of the nonparametric Mann-Whitney U test for analysis of this indicator.

Lastly, the level of satisfaction (LS) results showed that the data for both groups were normally distributed, with the CG at a p-value of 0.18 and the EG at 0.46. Consequently, the parametric T-Student test was utilized to analyse this indicator.

Table 7. Outcomes of hypothesis evaluations for each indicator

Research Indicator	Statistical Test	Statistical Test Result (p)
LKR	Mann-Whitney U	< .001
LU	T-Student	0.027
LM	Mann-Whitney U	0.001
LS	T-Student	0.013

In Table 7, the statistical analysis highlighted significant findings across all indicators. The Mann-Whitney U non-parametric statistical test for the level of knowledge retention (LKR) registered a p-value of less than .001, indicating a significant difference between the control group (CG) and the experimental group (EG). Similarly, the t-student parametric statistical test for the level of understanding (LU) yielded a p-value of 0.027, confirming notable differences.

Furthermore, the level of motivation (LM), when analysed using the Mann-Whitney U Test, resulted in a value of 0.001making it significant as a result. Similarly, the level of satisfaction (LS), evaluated through the t-student test, yielded significant findings with a p-value of 0.013. These findings provide robust statistical evidence to reject the null hypothesis and support the alternative hypothesis for each assessed indicator.

6. Discussion

This section discusses the impact of using a serious video game on learning outcomes related to software design patterns. It explores how this approach influences knowledge retention, understanding, motivation, and satisfaction, comparing the experimental group's results with those of the control group. The analysis draws on data collected during the study and situates the findings within the broader context of existing research.

The findings demonstrate that employing a serious video game significantly boosted learning outcomes related to software design patterns. This approach enhanced knowledge retention, understanding, motivation, and satisfaction, confirming the game's efficacy in improving educational results in these areas. Specifically, in a private university in Trujillo, the deployment of this game led to notable improvements in learning these patterns, echoing the positive outcomes observed in studies like those conducted by González *et al.* [2].

For instance, when examining the level of knowledge retention (LKR), the control group scored an average of 9 points, while the experimental group scored 14, marking a 5-point increase. This translates to a 45% retention rate for the control group versus 70% for the experimental group, indicating a 25% uplift for those who engaged with the video game. This improvement mirrors findings from Aedo *et al.* [9], who noted similar enhancements in retention rates.

In analyzing the level of understanding (LU), the control group's average was 7 points, with the experimental group slightly higher at 8 points. This 1-point increase corresponds to a 35% to 40% understanding rate between the control and experimental groups, respectively, demonstrating a 5% enhancement. This aligns with findings by Jaimez-González [7], where understanding rates reached as high as 90%.

Regarding the level of motivation (LM), the control group's average scores were 3.38 while the experimental group's were 3.84, demonstrating a 0.46 point increase.

This translates to an improvement from 67.6% to 76.8% in motivational levels, a 9.2% rise, which aligns with the 57.1% level reported in Santillana's study [8].

For the level of satisfaction (LS), the average scores increased from 3.20 in the control group to 3.70 in the experimental group, representing a 0.50-point increase. This indicates a 10% boost in satisfaction levels, increasing from 64% to 74%, which is comparable to the nearly 100% satisfaction levels found in Beltrán's study [6].

Despite these positive outcomes, the study faced limitations such as insufficient development time due to technical issues with the laptop used for software development and challenges in ensuring consistent student engagement with the game. Additionally, the game's development was constrained by the limited technical expertise in video game programming within the Unity environment available to the researchers.

In conclusion, the use of a serious video game at a Private University of Trujillo significantly enhanced the learning of software design patterns. The improvements across various educational metrics suggest that this method could serve as a valuable reference and blueprint for future educational endeavors to further refine the learning process of software design patterns.

7. Conclusion

This section summarizes the overall findings of the study, highlighting the significant improvements in learning outcomes attributed to the use of a serious video game. It examines the statistical evidence supporting the enhanced retention, understanding, motivation, and satisfaction among students, reinforcing the potential of serious games as effective educational tools.

The study revealed that using a serious video game significantly enhanced the level of knowledge retention (LKR) for software design patterns. Specifically, the control group achieved a 45% retention rate, while the experimental group reached 70%, marking a 25% improvement due to the gaming intervention. This substantial increase, confirmed by a p-value of less than .001 from the Mann-Whitney U test, supports the alternative hypothesis.

Additionally, there was a noticeable improvement in the level of understanding (LU) of software design patterns, where the control group's understanding was 35% compared to 40% in the experimental group. This 5% boost, substantiated by a p-value of 0.027 from the t-student test, validates the alternative hypothesis for this indicator.

In terms of motivation, the level of motivation (LM) showed a significant uplift from 67.6% in the control group to 76.8% in the experimental group, indicating a 9.2% increase. The change, verified by a Mann-Whitney U test with a p-value of 0.001, adequately supports the alternative hypothesis.

Finally, the level of satisfaction (LS) demonstrated substantial growth, with the control group recording 64% satisfaction compared to 74% in the experimental group, reflecting a 10% increase. The t-student test confirmed this improvement with a p-value of 0.013, providing strong statistical backing to accept the alternative hypothesis.

Overall, the study's findings underscore the effectiveness of the serious video game in boosting retention, understanding, motivation, and satisfaction levels among learners, with each indicator's increase backed by rigorous statistical testing.

References:

[1]. Soto-Duran, D. E., Reyes-Gamboa, A. X., Giraldo-Mejía, J. C., Villamizar-Jaimes, A., & Vidal-Alegría, F. A. (2022). Buenas prácticas para el desarrollo de software sostenible. *Revista Ibérica de Sistemas e Tecnologias de Informação*.

[2]. González, L. E., Marroquín, S. V., Maturana, G. V., & Manjarrés, R. A. (2021). Coffee Challenge: Un juego para la enseñanza de patrones de diseño de software. *Revista Politécnica*, *17*(33). Doi: 10.33571/rpolitec.v17n33a3

[3]. Ferrandis, A. (2021). *Desarrollo de una herramienta para el aprendizaje de patrones de diseño software* [Doctoral dissertation, Universitat Politècnica de València].

[4]. Esteban, N. (2018). Tipos de Investigación. Universidad Santo Domingo de Guzmán. *Repositorio Institucional.*

[5]. Zhu, L., Cao, Q., & Cai, Y. (2020). Development of augmented reality serious games with a vibrotactile feedback jacket. *Virtual Reality & Intelligent Hardware*, *2*(5). Doi: 10.1016/j.vrih.2020.05.005

[6]. Beltrán, J. T. (2017). *E-learning y gamificación como apoyo al aprendizaje de programación,* [Doctoral thesis, Universidad de Extremadura].

[7]. Jaimez-González, C. R. (2019). Evaluación de recursos didácticos en línea para apoyar el proceso enseñanza-aprendizaje de la programación web con JavaScript y Java Server Pages. *Dilemas Contemporáneos: Educación, Política y Valores*, *6*(3), 1-23.

[8]. Santillana, M. C. (2020). *La gamificación como motivación para el aprendizaje del curso de programación en estudiantes de un instituto de educación superior de la región Arequipa*. [Thesis, Pontificia Universidad Católica Del Perú].

[9]. Lopez, M. A., Cornejo-Aparicio, V., & Flores-Silva, S. (2021). Experiencia en la Aplicación de un Videojuego Geolocalizado para comprender los conceptos fundamentales del Paradigma de la Programación Orientada a Objetos. *Revista Ibérica de Sistemas e Tecnologias de Informação*, 452-462.

[10]. Díaz, E. (2012). Estilos de Aprendizaje. *Eídos*, *4*(*5*), 5-11. Doi: 10.29019/eidos.v0i5.88

[11]. Estrada, A. (2018). Estilos de aprendizaje y rendimiento académico. *Revista Boletín Redipe*, *7*(7), 218-228.

[12]. Sánchez, E. (2004). El proceso de enseñanza-aprendizaje. Madrid: Universidad Complutense.

[13]. Aparicio, J. A., Hoyos, O., & Niebles, R. (2004). De Velázquez a Dalí: las concepciones implícitas de los profesores sobre el aprendizaje. *Psicología desde el Caribe*, (13), 144-168.

[14]. González, C. R. G. (2014). Las dimensiones de la gestión del conocimiento y los procesos de desarrollo local comunitario. *Acta Universitaria*, *24*(1), 60-68.

[15]. González, A. O. (2019). La comprensión en acción: un análisis sobre sus niveles y cualidades. *Revista Pilquen. Sección Psicopedagogía*, *16*(2), 59-74.

[16]. Cedeño, M. C., Veliz, V. F., & Mendoza, K. L. (2021). Enseñanza: La comprensión para el aprendizaje mediante las inteligencias múltiples o habilidades del pensamiento. *Estudios del Desarrollo Social: Cuba y América Latina*, *9*(2).

[17]. Méndez, C. R., Almache, W. R., & Gallegos, M. F. (2022). Motivación y satisfacción: Variables psicológicas influyentes en el rendimiento académico virtual. *Revista Scientific*, *7*(24). Doi:10.29394/Scientific.issn.2542-2987.2022.7.24.2.37-55

[18]. López, M. V., & Sánchez, S. (2018). Relación entre la madurez vocacional y la motivación hacia el aprendizaje académico. *Revista INFAD de Psicología. International Journal of Developmental and Educational Psychology*, *1*(1). Doi: 10.17060/ijodaep.2018.n1.v1.1150

[19]. Arras, A. M. de G., Gutiérrez, M. del C., & Bordas, J. L. (2017). Escenarios de aprendizaje y satisfacción estudiantil en posgrado virtual 2010, 2014 y 2015. *Apertura (Guadalajara, Jal.)*, *9*(1), 110-125. Doi: 10.32870/ap.v9n1.918

[20]. Paredes-Otero, G. (2022). Narrativas y usuarios de la sociedad transmedia. *Narrativas y Usuarios de La Sociedad Transmedia*, 1-888.

[21]. Guerra Antequera, J. (2017). *Estudio evaluativo de prevención del acoso escolar con un videojuego* [Doctoral Thesis, Universidad de Extremadura].

[22]. Massa, S. M., & Bacino, G. A. (2017). *Videojuegos en Serio Creando Serious Games para aprender jugando*. Universidad Nacional de Mar del Plata.

[23]. Aguilar, C. J., Chanchí, G. E., & Vidal, M. I. (2017). Definición de un proceso metodológico para la construcción de juegos serios para el apoyo de la enseñanza de la física cinemática. *Publicaciones e Investigación*, *12*(1), 35-48.

[24]. Acerenza, N., Coppes, A., Mesa, G., Viera, A., Fernández, E., Laurenzo, T., & Vallespir, D. (2009). Una Metodología para desarrollo de videojuegos. *PEDECIBA Informática*.

[25]. Chero, J. G. (2019). *Estudio de usabilidad de videojuegos web utilizando la metodología de desarrollo sum.* UTMACH.